London County Council.

BACTERIAL TREATMENT OF CRUDE SEWAGE.

THIRD REPORT

BY

Dr. CLOWES AND Dr. HOUSTON.

EXPERIMENTAL INTERMITTENT TREATMENT

OF

LONDON CRUDE SEWAGE

IN

THE COKE-BEDS AT BARKING AND CROSSNESS.

PRESENTED BY

PROFESSOR FRANK CLOWES, D.Sc. (Lond.), F.I.C.
(Chief Chemist to the Council),

To the Main Drainage Committee of the Council,

On 24th May, 1900.

(WITH APPENDIX UP TO JULY 28th, 1900.)

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DIVISION I.—CHEMICAL AND GENERAL

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DIVISION I.—CHEMICAL AND GENERAL.

I.—INTRODUCTORY SUMMARY.

Early in 1898 a First Report was printed by the Council on the bacteriological examination, by Dr. Houston, of London crude sewage as it arrived at the Outfalls at Barking and Crossness. This was followed by a Second Report, giving the results obtained by the chemical and bacteriological examination of the crude sewage and of the effluent from the coke-beds at Crossness. A Supplementary Report on the deposit found upon the coke of the coke-beds was issued in October, 1899.

The present Report gives a similar statement of the results obtained in the experimental bacterial treatment which has been carried out at the Northern Outfall (Barking) and of the experimental treatment carried out at the Southern Outfall (Crossness) since the issue of the last Report.

The superintendence of the chemical work has rested in the hands of Mr. E. Brooke Pike, the chemist at the Northern Outfall, and of Mr. J. W. H. Biggs, the chemist at the Southern Outfall, and the successful carrying out of the processes has been due to the careful work of these gentlemen and to the co-operation of Messrs. H. Stokoe and E. J. Beal, superintendents at the Outfalls.

The bacteriological work has been in the hands of Dr. Houston, who makes a separate statement of his results in Division II. of this Report.

The process employed at both Outfalls has been that of " intermittent contact " with frequent aëration of the coke surfaces.

The acre coke-bed at the Northern Outfall has received an effluent resulting from sewage which has been mixed with solutions of lime and iron sulphate and has then been subjected to sedimentation. The smaller coke-beds have received sewage which has not been mixed with chemicals, and which has, as a rule, not been freed from its suspended solid matter by sedimentation.

Since the cellulose substances in the suspended solid matter of the sewage are only dealt with slowly by the bacteria in the coke-bed, they tend to accumulate on the coke and to diminish the sewage capacity of the bed; they also tend to diminish the extent of purification from the dissolved organic matters of the sewage. Hence the acre bed, which receives the effluent from chemically treated and sedimented sewage, has yielded better results than the smaller experimental beds.

A very rough process of sedimentation of the sewage, without the use of chemicals, was effected at the Southern Outfall by allowing the crude sewage to flow through a large tank on its way to the coke-bed. This sedimentation considerably retarded the choking of the coke-beds.

Last Christmas an experiment was made (see page 15) on the whole of the South London sewage by allowing it to flow at a comparatively rapid pace through one of the large settling channels at the Outfall Works. In this way the larger portion of the solid suspended matter of the sewage was deposited; a portion of the effluent from this sedimentation process was treated in a small bacterial coke-tank and was found to undergo the usual amount of purification, and to furnish an almost clear and entirely inoffensive and nonputrescible effluent. No reduction in the capacity of the coke-bed occurred during the period of experiment.

From this experiment it may be inferred that simple rapid sedimentation of the crude sewage on the large scale, followed by intermittent bacterial coke treatment will furnish an effluent suitable for the lower river, together with a sludge deposit which could be dealt with in the usual way.

It seems reasonable that the experimental treatment of the sewage by rough screening, followed by rapid sedimentation without the previous introduction of chemicals, might now be attempted on a larger scale, and that by this means an effluent of much greater purity than that at present discharged might be sent into the river.

It will be seen that the general result of experience with the various coke-beds has been that they increase in efficiency as the duration of their service increases, and that some considerable period of service is necessary before they exert their maximum amount of purification of the sewage.

Dr. Houston summarises on pp. 41 to 53 the previous Reports issued by the Council, and gives on pp. 54 to 78 details of the bacteriological work which he has carried out since the issue of those Reports.

As regards the general bacteriological aspect of the treatment of London sewage, Dr. Houston gives a statement of the conclusions at which he has arrived after two years study of the problem on behalf of the Council (pp. 70 to 71). It will be seen that Dr. Houston concurs in the advisability of adopting the bacterial method of treatment of London sewage in place of the chemical treatment, and maintains that under the conditions existing in the lower river and at the Outfalls, this system of treatment would furnish a more satisfactory result. But he states that although the effluent from the bacterial beds would not lead to nuisance in the river, it would be by no means a satisfactory liquid to introduce into a part of the river which was used for drinking purposes.

II.—EXPERIMENTAL BACTERIAL TREATMENT OF CRUDE SEWAGE AT THE NORTHERN OUTFALL WORKS (BARKING).

1.—PRIMARY AND SECONDARY TREATMENT IN BEDS OF KENTISH RAGSTONE AND COKE, 5 FEET IN DEPTH.

For the purpose of these experiments four galvanised iron tanks, 4 feet square by 6 feet in depth were erected on some waste land at the liming station and were filled with material to a depth of 5 feet, and were so arranged that the effluent from the two primary tanks should drain completely into the two corresponding secondary tanks. The crude sewage supplied to the beds was obtained from a large pipe conveying sewage to the overhead lime tank, and was raised by means of a portable auxiliary pump. This pump was stopped for a few days periodically for cleaning, and on these occasions the bacteria beds could not be filled.

On the 21st of July, 1898, it was suggested that in series I. the first tank should contain a coarse bed of large coke and should discharge its effluent into a fine bed of small coke. Series II. should consist of a coarse bed of large pieces of Kentish ragstone, and should discharge its effluent into a fine bed of the same material. It seemed desirable to experiment with the Kentish ragstone, on account of its great durability and its acid-neutralising power.

It seemed probable that the calcium carbonate in the ragstone would furnish a base for the neutralisation of the nitric acid formed by the bacterial action.

The material employed in the two coarse primary beds of coke and ragstone was of such a size that the pieces would pass a 4-inch mesh and be rejected by a $\frac{1}{2}$-inch mesh. The material in the two fine beds was of such a size that it would pass a $\frac{1}{2}$-inch mesh and be rejected by a $\frac{1}{16}$th-inch mesh.

The procedure was as follows—

The two coarse beds were filled with crude sewage simultaneously and as quickly as possible to a level with the top of the solid material; the beds were allowed to remain full for two hours, and were then drained into the fine beds. These remained full for two hours, and were then drained off. During the outflow of the effluent from each bed it was sampled every few minutes. These samples were mixed, and the average liquid thus obtained was subjected to analysis. The crude sewage with which the primary beds were filled was sampled and examined in a similar manner.

The beds were first filled with crude sewage on the 22nd of September, 1898, and their capacity was ascertained a week later by the careful measurement of the effluent while they were being emptied. On the 29th September the capacity of the coarse beds was as follows—

Description of bed.	Capacity of each bed in gallons.	Percentage of whole volume of bed.	Corresponding capacity per acre of bed.
Ragstone	200	40·0	544,500
Coke	250	50·0	680,625

The beds received one filling daily until January 11th, 1899, and then two fillings daily until the experiments were stopped. Before starting the two daily fillings the capacity of the beds was ascertained to be as follows—

Description of bed.	Capacity of each bed in gallons.	Percentage of whole volume of bed.	Corresponding capacity per acre of bed.
Ragstone	183	36·6	498,217
Coke	195	39·0	530,887

Two daily fillings would represent a million gallons per acre per day.

On January 20th, 1899, an attempt was made to estimate the free oxygen in solution in the effluents from the four beds, and the following results were obtained—

Ragstone, coarse bed	nil.
Coke "	nil.
Ragstone, fine bed	18·0 per cent.
Coke "	19·1 "

Complete saturation with oxygen was taken as 100.

The effluent obtained from the primary beds did not show as high a purification as had been expected; it is probable that the large size of the material had the effect of presenting an insufficient surface of contact with the sewage; the putrescible matter in the sewage was not therefore thoroughly dealt with by the bacteria.

On March 9th, 1899, the capacity of the beds was ascertained to be as follows—

Description of bed.	Capacity of each bed in gallons.	Percentage of whole volume of bed.	Corresponding capacity per acre of bed.
Ragstone	174	34·8	473,715
Coke	168	33·6	457,380

Table A (page 9) shows the varying capacities of these beds, and proves that the coke-beds became choked more quickly than the ragstone-beds.

During the first four months after starting the primary coke-bed it choked at the rate of 3·6 gallons per week, or 0·73 per cent. of the total capacity of the tank, and during the next two months the rate of choking was 3·4 gallons per week, or 0·68 per cent. of the total capacity of the tank. The ragstone-bed during the six months choked regularly at the rate of 1·1 gallons per week, or 0·22 per cent. of the total capacity of the tank.

Early in April, 1899, it was considered that the beds had reached their maximum power for purifying the sewage. They were then being filled twice a day, and were dealing with the sewage at the following rates—Ragstone, 947,430 gallons per acre per day; coke, 914,760 gallons per acre per day, and the average percentage purification effected during that month was—

Description of bed.	Percentage purification, as measured by oxygen absorbed from permanganate.	Percentage purification, as measured by albuminoid ammonia.
Ragstone, primary, coarse bed	17·5	32·6
Coke ,, ,, ...	16·5	21·3
Ragstone, secondary, fine bed	48·8	64·4
Coke ,, ,, ...	60·9	62·4

The amount of nitrification produced had fallen very low in the case of all the beds.

Abnormal amounts of nitrate were found in the first effluent from the ragstone fine bed after the bed had rested at Easter, from 29th March until 5th April, and it appeared probable that nitrates had been formed in the bed during the rest and had then been washed out by the first filling with sewage. A similar result was not found in any of the other beds.

The series of experiments with these beds terminated on the 15th April, 1899, after a period of 29 weeks' working. The average percentage purification effected during the last week was as follows—

Description of bed.	Percentage purification, as measured by oxygen absorbed from permanganate.	Percentage purification, as measured by albuminoid ammonia.
Ragstone, coarse bed	21·3	43·2
Coke ,, ...	18·8	29·7
Ragstone, fine bed	50·7	66·5
Coke ,, ...	58·5	68·6

The average percentage purification during the continuance of the experiments as measured by the oxygen absorbed from permanganate in four hours was as follows—

Ragstone coarse bed	20·6
Coke ,, ...	22·5
Ragstone fine bed	49·1
Coke ,, ...	63·2

The two coarse beds were thus shown to be doing very unsatisfactory work. It was hoped that an improved effect would be produced if a reduction were made in the size of the material in the bed. That this expectation was justified will be seen by the fact that the results obtained in the next series of experiments, when the primary beds were composed of coke fragments one-half to two inches in diameter, showed an average purification of 43·8 per cent.

With regard to the secondary treatment of the primary effluent with fine material, the results furnished by the ragstone did not at all come up to expectations, and were far less satisfactory than those obtained with the coke. The amount of nitrification produced by this bed was, however, much greater than that produced in the corresponding coke-bed. It has recently been shown that the presence of nitrates in an effluent may prevent the putrifaction of a certain amount of organic substances from occurring in another effluent with which the nitrate-effluent has been mixed; hence the nitrifying power of the ragstone beds is not without importance.

The beds were filled once a day from 22nd September, 1898, to 9th January, 1899, both inclusive. The filling was, however, not carried out on Sundays or on Christmas holidays, and occasionally one or two days were missed when the boiler was undergoing cleaning. In all, filling was carried on on 83 days out of the 110. During this period the ragstone-beds dealt with a total of 16,800 gallons, which was equivalent to 115,800 gallons per acre per day, including all resting periods; while the coke-beds dealt with one-fourth more than this quantity. From 11th January, 1899, to 15th April, 1899, when the experiment terminated, the beds were filled twice daily on 73 days out of the total of 95. During this period the ragstone-beds dealt with a total of 20,976 gallons, which is equivalent to 601,128 gallons per acre per day, while the coke-beds dealt with a total of 21,864 gallons, equivalent to 626,576 gallons per acre per day, all resting periods included. The total volume of sewage dealt with over the whole period of the experiment was therefore—

Ragstone beds	37,776 gallons.
Coke beds	42,864 ,,

Expressed in terms of an acre these quantities would represent, on the days the beds were actually at work during the first period of the experiment with one filling per day, the following volumes—

Ragstone	551,060 gallons per acre per day.
Coke	688,825 ,, ,, ,,

and during the second period of the experiment, with two fillings per day—

Ragstone	782,290 gallons per acre per day.
Coke	815,407 ,, ,, ,,

The detailed results obtained by the chemical examination of the sewage and of the effluents are tabulated on pp. 17 to 19. The average purification, as measured by the oxygen absorbed from permanganate in four hours, during the whole continuance of the experiment was as follows—

Description of bed.	Oxygen absorbed from permanganate.	Percentage purification.
Ragstone, coarse bed	3·015	20·6
Coke ,, ...	2·944	22·5
Ragstone, fine bed	1·933	49·1
Coke ,, ...	1·396	63·2
Crude sewage, for comparison	3·797	

The average purification effected by one daily filling was—

Description of bed.	Oxygen absorbed.	Percentage purification.
Ragstone, coarse bed	3·003	20·2
Coke ,, ...	2·923	22·3
Ragstone, fine bed	2·002	46·8
Coke ,, ...	1·323	64·9
Crude sewage, for comparison	3·764	

The average purification effected during two fillings per day was—

Description of bed.	Oxygen absorbed.	Percentage purification.
Ragstone, coarse bed	3·028	21·0
Coke ,, ...	2·969	22·6
Ragstone, fine bed	1·855	51·6
Coke ,, ...	1·478	61·5
Crude sewage, for comparison	3·834	

It will thus be seen that coke gives better results than ragstone in the removal of organic matters in solution; the results are slightly better on the primary treatment, and considerably better on the secondary treatment. It will also be observed that, with the exception of the fine coke-bed, which showed a slight decline, two fillings a day gave a rather better result than was obtained with one filling per day, showing that although the purifying power of the beds, owing probably to the large size of the material, was in itself low and unsatisfactory, still the beds were not being overworked. It points to the conclusion that from 20 to 23 per cent. purification was all that could be obtained by a one-contact treatment of the unsedimented crude sewage dealt with in a bed composed of material of so large a size that it would pass a 4-inch mesh and be rejected by a ½-inch mesh.

Effect of the Effluents on Fish life—The effluents from the primary beds killed gold and silver fish in a few hours, but those from the secondary beds sustained fish life as readily as fresh tap-water does.

It should be stated that the raw sewage which was supplied to the beds was of the heaviest kind. It was drawn from a level about a foot from the bottom of the sewer, and passed through a ½-inch screen to the beds without any previous sedimentation.

Table A.—Variation in Percentage Capacity of the Primary Beds.

Ragstone 40	Coke 50	Already called "original capacity."
Ragstone 36·6	Coke 39	After an interval of 15 weeks.
Ragstone 34·8	Coke 33·6	After a further interval of 8 weeks.

The "original capacity" here shown was taken about 7 days after the experiments had been started; it is probably below the total capacity, since it was taken while the beds were being emptied, and the drainings of the beds were therefore not included. No doubt a more trustworthy method of estimating capacity consists in filling the bed after it has drained for a definite time, which should be the same in all processes of taking capacities. It might be well that a standard "drainage period" should be recognised generally, since the wetness of the bed-material must affect the so-called capacity considerably. Thus a bed which had been draining for one hour only would require less liquid to fill it than one which had been draining for ten hours. In the case of the one-acre bed at Barking it is known that the effluent will continue to drain away for several days.

2.—PRIMARY AND SECONDARY TREATMENT IN BEDS OF COKE 10 FEET IN DEPTH.

For the purpose of these experiments iron super-structures 4 feet in height were bolted to the existing tanks, and the joints were caulked and made watertight. Thus the depth of the tanks was increased to 10 feet. The tanks were then filled to a depth of 9 feet 9 inches with coke, and were worked in two series as follows—

Series A.—
(1.) A primary coarse bed. (A.)
(2.) A secondary coarse bed. (A 1.)

Series B.—
(1.) A primary coarse bed. (B.)
(2.) A secondary fine bed. (B 1.)

The three coarse beds were composed of coke of such a size that it would pass a 2-inch mesh and be rejected by a $\frac{1}{2}$-inch mesh.

The fine bed was composed of coke of a size which would pass a $\frac{1}{2}$-inch and be rejected by a $\frac{1}{16}$-inch mesh. In this instance the coke which had been in use in the previous experiments, and was thus in good bacterial condition, was mixed with two-fifths of its bulk of new material in forming the deeper bed. The arrangement of the tanks allowed the effluent from the primary beds to drain completely into their respective secondary beds.

The sewage supplied to the beds was obtained from the same source as during the previous experiments, and was thus of the strongest nature, and contained sand and other suspended mineral and vegetable matters which should not be allowed to reach the bed, and which a short period of sedimentation would, in a very great measure, remove. It speaks well for the beds that they have been able to cope so satisfactorily with the heavy work which was thrown upon them.

In series B the depth of the primary coarse bed was reduced to 9 feet 6 inches, in order that its liquid contents should not overflow when it passed into the secondary fine bed, whose capacity was somewhat smaller, owing to its being made of finer material.

The procedure was precisely similar to that adopted in the previous experiment. The two primary beds were filled simultaneously, were allowed to rest full for two hours; they were then drained into the secondary beds, and the effluent was allowed to remain for a further period of two hours in contact with the coke. The crude sewage and each of the effluents were separately sampled and subjected to examination.

Percentage Capacities of the Beds—The beds were charged by means of a fixed syphon made of one-inch pipe from an overhead water-tank, which was kept constantly full. The volume delivered by this syphon per minute was ascertained, and the capacity was then determined by the length of time required for filling each bed.

The following figures indicate the capacity of the various beds expressed as percentages of the total tank volume.

1899.	Primary coarse bed A.	Secondary coarse bed A 1.	Primary coarse bed B.	Secondary fine bed B 1.
29th May—dry coke ...	68·7	61·7	70·3	53·1
20th September ...	41·9	56·8	33·3	48·1
27th October	32·3	54·9	32·7	46·9
6th December ...	31·3	53·1	27·6	48·1
4th January, 1900 ...	26·8	50·6	24·7	47·0
7th February... ...	21·8	50·6	21·2	44·4

The progressive decrease in the capacity of the beds shows that they were choking. This cannot be wondered at, considering that the very worst of the sewage was being dealt with, and that sand and other solid matter was being admitted to the beds. Latterly, trouble had been experienced in filling the primary beds, owing to the accumulated mass of undissolved matters on the upper part of the beds. The beds, however, were doing very satisfactory purifying work, and were removing from 40 to 50 per cent. of the dissolved putrescible matters.

It was noticed that after seven months' work the coarse bed B had sunk to the extent of 6 inches. On 20th February, 1900, 9 inches of new coke, similar to that originally used, was placed on the top of this bed, and the depth of the bed was thus brought up to 9 feet 9 inches, as in the case of the other three tanks, the capacity of the bed having fallen sufficiently to prevent its contents from overflowing the secondary fine bed.

The decrease in the capacity of the beds was as follows—

Periods of working each bed.	Total loss in capacity in gallons.	Decrease in capacity per week	
		Stated in gallons.	Stated in percentage of original capacity.
Coarse bed A (primary)—			
September 20 to October 27, 1899 (5 weeks) ...	84	16·8	1·92
October 27 to December 6, 1899 (6 weeks) ...	20	3·3	0·17
December 6 to January 4, 1900 (4 weeks) ...	44	11·0	1·12
January 4 to February 7, 1900 (5 weeks) ...	48	9·6	1·00
Average loss per week*		9·8	1·00
Coarse bed B (primary)—			
September 20 to October 27, 1899	5	1·0	0·12
October 27 to December 6, 1899	49	8·2	0·85
December 6 to January 4, 1900	38	9·5	0·72
January 4 to February 7, 1900	33	6·6	0·70
Average loss per week*		6·3	0·60
Coarse bed A 1 (secondary)—			
September 20 to October 27, 1899	18	3·6	0·38
October 27 to December 6, 1899	19	3·2	0·30
December 6 to January 4, 1900	24	6·0	0·62
January 4 to February 7, 1900	nil	nil	nil
Average loss per week*		3·2	0·31
Fine bed B 1 (secondary)—			
September 20 to October 27, 1899	12	2·4	0·24
October 27 to December 6, 1899	12 (Increase in capacity)	2·0 (Increase)	0·20 (Increase)
December 6 to January 4, 1900	11	2·7	0·27
January 4 to February 7, 1900	26	5·2	0·52
Average loss per week*		1·9	0·19

Although the apparent average loss of capacity was much greater in coarse bed A than in coarse bed B (both primary), the actual capacity of B was slightly smaller than that of A, being 21·2 per cent., as against 21·8 per cent. in A. This is accounted for by the fact that a much greater decrease in capacity occurred in bed B before the 20th September than in bed A after the 20th September.

Work was commenced on Tuesday, 4th July, 1899, the beds receiving one filling per day up to 15th July, when it was thought advisable to fill the beds only three times in the week.

From 21st September the beds received one filling a day, and from 11th December onward two fillings a day.

The purification as measured by the amount of oxygen absorbed from permanganate, effected up to the end of the year 1899 is stated in the following table, in which the numbers in the first column represent the average percentage purification effected during the period when the beds were filled three times a week, the second column the period of one filling a day, the third column the period of two fillings a day, and the last column the average percentage purification effected by each bed from the commencement of the experiment until 31st December, 1899.

Description of bed.	Three fillings a week.	Six fillings a week.	Twelve fillings a week.	Average.
Primary coarse bed A	43·9	45·3	45·0	43·9
Secondary coarse bed A 1	62·3	63·6	61·1	62·5
Primary coarse bed B	43·5	45·3	43·9	43·8
Secondary fine bed B 1	79·1	76·1	67·6	76·2

A further improvement is observable in the efficiency of the beds since December 31st last up to the date of writing (10th February, 1900), the average percentage purification effected during that period having been as follows—

Primary coarse bed A	46·4
Secondary coarse bed A 1	64·2
Primary coarse bed B	47·3
Secondary fine bed B 1	71·0

* This average is calculated from the total loss of capacity which took place during the 20 weeks of experiment.

Relative Temperatures of the Atmosphere and of the Sewage and Effluents.

In Table 2 (page 19) the detailed temperature readings of the atmosphere and the effluents during December, 1899, are given. From a general consideration of the averages of these readings it appears that when the atmosphere was at a temperature of 38·5° Fahr. the sewage flowed into the primary beds at a temperature of 53° Fahr.; and that after it had remained in the primary beds for two hours it flowed into the secondary beds at a temperature of 46° from bed A and of 44·5° from bed B, the air temperature at that time being 38·0°. After the sewage had remained in the secondary beds for two hours it was drawn off, and showed a temperature of 44° from bed A1, and 42·5° from bed B1, the air temperature at the time being 37·5°. It will be observed that the average temperature of the outside air fell during the whole process 1° Fahr., and that the sewage fell 7° while it remained for two hours in the primary bed A, and a further 2° while it remained another two hours in the secondary bed A 1, or 9 degrees out of a possible 15·5 degrees' fall during the whole process. In series B the sewage fell in temperature 8·5° after two hours' rest in the primary bed and a further 2° after another two hours in the secondary bed, or 10·5 degrees out of a possible fall of 15·5 degrees during the whole process.

In considering this question of temperatures the following facts must be borne in mind—(1) that the beds were small in area; (2) that their position was exposed, that they stood in metal tanks supported entirely above the ground level, and that each tank was widely separated from the others; and (3) that since the tanks were constructed of thin galvanised iron, their exteriors readily lost heat by radiation as well as by contact with the cold air.

The somewhat lower temperatures found in series B are explained by the fact that the latter is somewhat more exposed than series A, which stands between series B and a wooden wind-screen.

In another series of readings which are given in Table 3 (page 20) the air temperature fell 2·5° Fahr. during the process of treatment of the sewage—from 43·5° to 41°; and the temperature of the sewage fell in both series of beds (A and B) 4·5° in its passage through the primary beds, and 1 degree more in passing through the secondary beds—a total fall of 5·5° out of a possible 9·5°. In series A the temperature of the beds themselves was taken about four hours after they had been emptied, and the average temperature of the primary bed was found to be equal to that of the sewage which had flowed into the bed, viz., 50·5° Fahr., while the outside air stood at 42°. The average temperature of the interior of the secondary bed was 48°, or 2° higher than that of the effluent from the primary bed with which it had been filled, and 3° above that of the effluent when it was drawn off four hours previous to the test, the outside air standing at 41° Fahr.

These details may be summarised as follows—The temperature of the liquid, while it was standing in the primary bed, fell 4·5 Fahr., but after the liquid had been drawn off, the bed recovered from this loss of temperature in four hours; this recovery could evidently only be effected by some internal action which was attended with the production of heat, and is probably due to the action of the bacteria upon the moist suspended matters contained in the bed. The liquid, in passing through the secondary bed, lost a further degree in temperature, but the bed, after standing empty for four hours, rose in temperature again to the extent of 3° Fahr.

Composition of the Air contained in the Body of the Primary Bed B.

Many analyses were made of the air contained in the empty coke-beds. The detailed results are given in Table 4 (pp. 20 and 21). From the 19th October to the end of 1899 the air present in the intertices of the coke-bed, after it had remained empty for the average time of twenty-one hours on several different occasions, contained the following average percentages of oxygen and carbon dioxide—

Oxygen	10·3
Carbon dioxide	5·7

Between January 1st and February 23rd, 1900, when the bed had remained empty on many occasions for an average period of five hours, the following average percentages were found in the interstitial air—

Oxygen	8·0
Carbon dioxide	5·7

Fresh air contains on an average the following percentages—

Oxygen	20·96
Carbon dioxide	0·04

The average proportion of oxygen present in the air at the bottom of the bed, as compared with that present in fresh air therefore was, up to the end of 1899, with the bed standing empty for twenty-one hours, about 50 per cent. From the commencement of the present year until 23rd February, with the bed standing empty for the average period of five hours, the aëration, as measured by the above proportion of oxygen, has been about 38 per cent. This is by no means so satisfactory a condition as could be desired, and is probably due to the fact that the bed had become clogged by the heavy suspended matters of the crude sewage, and that the putrifactive bacteria acting on these matters rapidly absorb oxygen from the air and liberate carbon dioxide and other gases.

Suitability of the Effluent to Maintain Fish life.—The effluent from the primary beds was capable of sustaining the life of gold fish apparently indefinitely. Less hardy fish, such as roach, dace, and perch, became sickly after living in the effluent for a week or two. It should be remarked, however, that the fish were in a somewhat sickly condition before they were placed in the effluent.

Nitrification.—The average amount of nitrification produced by the nitrifying organisms in the various beds up to 31st December, 1899, is indicated by the following numbers—

Description of liquid examined.	Weight of oxidised nitrogen present in the sewage and in the effluent in grains per gallon.	
	Nitrous nitrogen.	Nitric nitrogen.
Crude Sewage	0·0040	0·1602
Effluent from Primary coarse bed A	0·0932	0·4474
" " " B	0·0645	0·3562
" Secondary coarse bed A 1	0·0767	0·9279
" Secondary fine bed B 1	0·0409	1·5861

It will be seen that the sewage arrived at the works containing an average amount of 0·1602 grains per gallon of nitric nitrogen, which shows that it was fairly fresh. It contained, as a rule, no nitrous nitrogen.

Comparing the amounts of oxidation of nitrogen produced in the various bed, the amount of nitrous oxidation effected in the primary beds was reduced by 17·7 per cent. in the secondary coarse bed and by 36·6 per cent. in the secondary fine bed. On the other hand the amount of nitric oxidation effected in the primary beds was increased by 107·4 per cent. in the secondary coarse bed and by 345·3 per cent. in the secondary fine bed.

3.—THE BACTERIAL TREATMENT OF THE SEDIMENTED CHEMICAL EFFLUENT IN THE ONE ACRE SIX-FEET COKE-BED.

The one-acre coke-bed, as it was originally laid down, consisted of three feet of unsifted pan breeze obtained from the adjacent Beckton Gas Works. In 1898 the depth was increased to 6 feet by placing on the top of the old bed 3 feet of coke, in pieces from half-an-inch to one inch in diameter and sifted free from dust. Its area was really 5,067 square yards instead of 4,840 square yards.

The bed was first filled on 29th April, 1898, in order to test the pipes for leakage, and it was observed that the surface of the bed settled down considerably in the central portion. The bed was re-levelled and work was re-commenced on the 12th May, 1898. On the following day the effluent from the bed showed a purification of 81·2 per cent. as compared with the chemical effluent, which was allowed to flow upon this bed. The bed was filled once a day until 2nd July, 1898, from after that date one filling per tide was dealt with: this amounted practically to two fillings a day. The bed had to be worked according to the tide, because high-water mark in the river, into which the effluent was discharged, was above the level of the outfall for the effluent.

Quantities of chemical effluent dealt with and capacity of the bed.

The bed was filled once a day between 12th May, 1898, and 2nd July, 1898, with the exception of Sundays, when the bed rested empty. During this period the bed was filled 43 times, and dealt with a total volume of 29,986,048 gallons, or an average of 697,350 gallons at each filling. As the total capacity of the space occupied by the bed is 273,618 cubic feet, or 1,710,112 gallons, the bed showed a liquid capacity of 40·8 per cent. of its whole volume. During the period under notice the capacity of the bed, as calculated from the averages of the first and last complete week's work, fell 71,045 gallons, this being equal to a decrease of 4·15 per cent. during the the whole period, or to 0·59 per cent. per week.

During the week ending July 9th, 1898, the bed was dealing with sewage at the rate of 1,255,918 gallons a day for six days in the week, and resting on the seventh. This quantity is approximately equal to that dealt with by the old 3-foot bed when it was at its maximum working capacity and being filled three times a day.

As the effluent appeared to drain off very slowly from the bed, the engineer obtained the sanction of the Committee to construct a second outlet in order to hasten the process of emptying this bed. For this purpose the bed was thrown out of work on Friday, 29th July, 1898. The capacity of the bed at this time was 508,250 gallons, or 29·7 per cent. This is a fall of 12·2 per cent. from the average capacity during the week ending May 21st, 1898. The average capacity during this week was 717,503 gallons, and the last filling on the 29th July had shown 508,250 gallons.

The purification effected during the period from May 12th to 29th July, 1898, as shown by the oxygen consumed, averaged 79·7 per cent.

The regular filling of the bed was commenced again on 8th November, 1898. During the first two weeks after starting, the bed was filled once a day, but the work done was so efficient that tidal fillings were resumed on 21st November, and continued until 11th March, 1899, when the bed became foul and was thrown out of work. During this period (November 8th, 1898, to March 11th, 1899) the bed dealt with 98,743,447 gallons and effected an average purification of 84·3 per cent.

At the commencement of this period the capacity of the bed was 39·7 per cent.; at the end of the period it was 29·1 per cent. This is equal to a drop of 10·6 per cent. in seventeen weeks, or 0·6 per cent. per week.

The bed rested empty for eight weeks and was started again on 8th May, 1899. It was filled once a day during the first three days of this week, and rested empty until the Monday following in order to enable the engineer to carry out some experiments relative to the cost of

sifting the material composing the lower three feet of the bed. The bed was then filled once a day until the 30th May, when tidal fillings were again commenced.

Between the 8th May and 31st December, 1899, the bed was filled 361 times, and dealt with a total of 170,191,973 gallons, or with an average of 471,446 gallons per filling. This gives an average capacity of 27·6 per cent., or 1·5 per cent. lower than 11th March. The actual fall in capacity between the middle of May and the end of December, 1899, was 7·7 per cent. Since the end of the year 1899 the capacity has gradually diminished until it reached, on 3rd March, 1900, 21·8 per cent., and 20·1 per cent. on 21st April.

The purification effected during the period extending from the 8th May to 31st December, 1899, averaged 82 per cent., as measured by the removal of the dissolved oxidisable matters from the chemical effluent. The results of these examinations are given in Table 7 pp. 25 to 34.

On February 20th a hole was dug to the bottom of the bed after it had been draining for five or six hours, and it was found that liquid remained in the bed filling it to the surface of the old 3-feet bed. The water could be baled out, but the hole filled itself again by the liquid oozing very slowly through its sides from the surrounding parts of the bed. In other words the lower half of the bed remained permanently full of liquid. This was probably due to the consolidation of the unsifted fine pan breeze in the lower part of the bed by the weight of the upper layer of three feet; this upper part being coarse-sifted coke apparently remained open and unconsolidated. The liquid contents of the lower three feet of the bed were accordingly only forced through the drain-pipes during the process of emptying by the weight of liquid in the upper half of the bed, and as soon as the contents of the upper three feet reached the lower three feet of the bed they remained there while the bed was resting in air until they were forced out after the next filling. It appeared therefore that only the upper three feet of the bed was aërated by direct contact with the air when the effluent flowed out, and that the lower three feet of the bed must have obtained its oxygen from the liquid which had been in contact with the upper half of the bed. This condition of things probably explains the low nitrification which has always been found in effluents from this bed, as compared with those derived from other experimental beds in use on the works. It explains also the low liquid capacity of this bed. In all probability the liquid capacity was nearly double that which was shown by measuring the volume of the effluent discharged. The capacity measured was indeed that of the upper half of the bed only, the lower half remaining entirely filled with liquid.

III.—REPORT AS TO FURTHER EXPERIMENTS ON THE BACTERIAL TREATMENT OF CRUDE SEWAGE AT THE SOUTHERN OUTFALL (CROSSNESS).

1.—INTERMITTENT TREATMENT OF CRUDE SEWAGE BY SINGLE CONTACT IN A COKE-BED 13 FEET IN DEPTH.

A brick-lined tank, 22 feet 6 inches long by 10 feet 8 inches wide, and having a superficial area equal to $\frac{2}{363}$ of an acre, had already been filled with coke to a depth of 6 feet for the experiments which were described in the previous Report on the Crossness Experiments. The coke fragments were about the size of walnuts. This 6-foot bed had been acting as a secondary bed for about eight months, and had treated the effluent from a coke-bed fed with crude sewage for that period.

On February 27th, 1899, this bed was first filled with crude sewage, and its depth was increased by adding new coke fragments of similar size to the old, until on March 8th the bed was 12 feet deep. On April 11th another foot of coke was added giving the bed a total depth of 13 feet. This increase in depth was made in order to ascertain whether an increase in the depth of the bed in any way detracted from its efficiency. It will be evident that the capacity of a bed per unit of superficial area is increased in proportion to this increase in its depth.

In charging this bed crude sewage was pumped by a special engine and pump direct from the suction culvert of the main pumping engines of the Outfall, and was distributed from a trough over the surface of the bed. The liquid sank readily into the body of the coke-bed.

As soon as the bed was filled and the liquid appeared at the surface of the bed, the pumping was stopped. The sewage was then allowed to remain in contact with the coke for three hours, after which it was allowed to flow away slowly from the bottom of the bed.

The filling took from 20 to 25 minutes, and the draining away of the effluent from an hour to an hour and a half.

From February 27th to March 25th inclusive, the bed was filled once daily with sewage, and after March 27th it was generally filled twice daily.

The bed was charged once only on Saturdays and remained empty on Sundays and on holidays. The other rests were due either to accidents occurring to the driving belt or to the pump, or to the necessity arising for making alterations in the arrangements or for making capacity determinations of the bed.

The coke which was used in this bed occupied, while it was new, 49 per cent. of the whole volume of the bed, and the interstitial air or liquid occupied 51 per cent. This liquid space was reduced by June 8th to about 34 per cent., and by October 10th to about 28 per cent. This loss in capacity was equal to about 63 gallons decrease of liquid capacity per week, and threatened speedily to put an end to the work of the bed. In order to prevent further loss of liquid capacity the coarser suspended matter of the crude sewage was allowed to subside before the sewage flowed upon the bed.

With this object a large wooden tank was placed upon the top of the coke-bed, and the crude sewage was pumped into this and was allowed to overflow upon the bed.

The solid matter left behind in the tank consisted mainly of particles of sand, woody fibre, straw, paper and hair. It was generally of the same character as the matter which had been found adhering to the coke and which had been choking the bed. The result of this rough settlement was that by January 12th, 1900, the liquid capacity had increased from 28 per cent. to about 33 per cent.

The purification effected by this bed, as judged by the removal of dissolved organic matter was practically equal to that obtained by the 4-foot bed.

There is no reason why a deep bed should not give as good results as a shallow bed, provided that it is as well aërated during the periods when it is empty. Experiments have been already reported which proved that even the bottom of the 13-foot bed was well supplied with oxygen.

The effluent from this deep coke-bed has been usually slightly turbid; it possessed only a faint earthy smell, and it was capable of supporting fish life.

During the period under notice, from February 27th, 1899, to December 22nd, 1899, the bed had been filled 338 times.

Taking the average sewage capacity of the bed as being equal to 6,000 gallons, the quantity of sewage dealt with per acre per day would be, for one filling, 1,089,000 gallons; for two fillings, 2,178,000 gallons; and for three fillings, 3,267,000 gallons.

Experiments are now in progress which will prove whether this bed is capable of treating sewage satisfactorily at the rate of four fillings a day, the sewage supplied to it having undergone a short process of preliminary sedimentation.

2.—EXPERIMENT ON THE BACTERIAL TREATMENT OF RAPIDLY SEDIMENTED CRUDE SEWAGE.

For three weeks at the end of last year the crude sewage arriving at the Southern Outfall was not mixed with chemicals, and was allowed to flow through one of the large settling channels at an average rate of 7·4 feet per minute, the usual rate of flow of chemically-treated sewage being about 1·5 feet per minute. A portion of this sedimented sewage was then treated in a small coke-bed in the intermittent manner already described, the bed being filled thrice daily. Details of the results obtained are given on page 38.

An average percentage purification from dissolved oxidisable matter was obtained, amounting to 53 per cent., calculated on the sedimented sewage; this purification amounted to 58·7 per cent., if calculated on the crudge sewage. The capacity of the bed was not reduced during the period of treatment.

3.—APPENDED REPORT ON THE 13-FOOT COKE BED. FEEDING WITH SEDIMENTED SEWAGE, AND INCREASED NUMBER OF FILLINGS PER TWENTY-FOUR HOURS. JANUARY 15TH TO JULY 28TH, 1900.

Continuing the history of this bed from the end of the last statement, the bed was not filled from December 22nd, 1899, to January 15th, 1900, owing to the experiments with the whole of the Crossness sewage being carried on at the same time.

From January 15th to April 5th, 1900, the bed was filled intermittently in the way already described, the sewage overflowing from a large wooden tank placed on the bed so as to allow the heavier and coarser suspended solids to settle out. The number of fillings per day is shown in the table which follows this statement.

On April 5th the bed had been filled with crude sewage three times daily for nearly 7 weeks. The coke was then seriously clogged upon the surface, and although the degree of purification effected was fully maintained, the bed had to be stopped in order to give time for the collection of matter in the upper part to become removed by bacterial action. The bed was allowed to stand in air from April 5th to May 2nd, 1900.

In the meantime, arrangements had been made to subject the sewage to a short, but more efficient, process of sedimentation in a brick tank of approximately 8,000 gallons capacity before it passed into the bed. The settled liquid was drawn off from near the surface of this tank, and as soon as the coke-bed had been filled the residual liquid remained at rest in the settling tank until it was again filled up with the crude sewage. Probably most of the liquid which passed into the coke-bed was therefore settled stale sewage, which was displaced by the incoming sewage. Some anaërobic (septic) bacterial action undoubtedly took place in this settling tank, and there was a considerable evolution of inflammable gas, but the extent by which the sludge was reduced in amount by this action could not be ascertained. The conditions of working would not allow of sufficiently accurate measurements of the incoming sludge being made, and an intermittent septic process of the above kind could hardly be suitable for dealing with the sewage of London.

Since May 2nd, the coke-bed has been filled intermittently from the brick settling tank three and four times daily; no clogging of the upper parts of the coke has been noticed, and the liquid sinks readily into the coke-bed as soon as it is allowed to pass upon the surface. The liquid capacity of the coke-bed was taken at long intervals, and has been found to be as follows—

January 12th—6,000 gallons.
June 16th—6,000 gallons.
October 8th—6,290 gallons (calculated from a determination of the capacity of half the bed).

The sludge deposited during eight weeks in the settling tank contained on the average 35 per cent. of organic matter.

Number of Fillings per Week of the 13-foot Coke Bed, and Weekly Average Purification.

Week ending	No. of fillings per week.	Average percentage purification as measured by the oxygen absorbed from permanganate in four hours.	
		By the total putrescible matter.	By the dissolved putrescible matter.
1900.			
January 20th	6	50·6	48·8
,, 27th	6	58·0	62·0
February 3rd	6	56·0	58·0
,, 10th	6	60·0	58·0
,, 17th	2	51·0	45·0
,, 24th	16	48·0	48·0
March 3rd	15	45·5	43·5
,, 10th	15	53·0	51·0
,, 17th	14	56·0	54·0
,, 24th	16	52·6	52·1
,, 31st	13	51·1	50·5
April 5th	9	49·0	51·0
,, 5th to May 2nd, rest for choking, alterations, &c.	—	—	—
May 5th	6	46·0	54·0
,, 12th	11	44·0	51·0
,, 19th	11	56·0	57·0
,, 26th	16	56·0	58·0
June 2nd	15	61·0	62·0
,, 9th	17	53·0	52·0
,, 16th	17	53·6	52·1
,, 23rd	20	58·0	54·0
,, 30th	21	55·0	47·0
July 7th	21	53·0	53·0
,, 14th	20	61·0	58·0
,, 21st	9	68·0	61·0
,, 28th	11	65·0	60·0
Total	319	Average 54·4	53·6

4.—LIQUID CAPACITY OF A COKE-BED, AS IT IS AFFECTED BY THE SIZE OF THE COKE FRAGMENTS.

The question has been raised as to the actual liquid capacity of one and the same tank according as it is filled with coke fragments of different sizes. It has been maintained that the liquid capacity of the interstices between the coke-fragments does not vary when the tank is successively filled with fragments of different dimensions, provided that in the case of each filling with coke the fragments are approximately of similar dimensions.

In order to test this a tank with a total capacity of 280 gallons was filled with small fragments of coke which passed a half-inch mesh, and subsequently with fragments about the size of the fist. In both cases the coke was allowed to soak in water until it was saturated, as was shown by the liquid capacity of the coke-tank becoming uniform when it was tested at intervals of several days. The period of soaking required was about four days. The liquid capacity was distinctly greater when the tank was filled with the large coke fragments than when it was filled with the small fragments. The relative capacities were as follows—

Capacity of small-coke bed	135 gallons.
,, large-coke bed	150 gallons.

Further experiments seemed to show that this difference in capacity increased as the particles departed more widely from the spherical form. With truly spherical particles of uniform size, the difference of capacity arising from difference in the size of the particles entirely disappeared.

IV.—TABULATION OF THE RESULTS OF THE CHEMICAL EXAMINATION OF THE BACTERIALLY-TREATED CRUDE SEWAGE AND EFFLUENTS.

I.—BARKING RESULTS.

TABLE 1.—CHEMICAL RESULTS OF THE ESTIMATION OF THE AMOUNT OF OXYGEN ABSORBED FROM PERMANGANATE BY THE SEWAGE AND BY THE EFFLUENTS FROM THE BEDS OF RAGSTONE AND COKE.

Date.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of— Crude sewage.	Effluent from the Ragstone series. Primary coarse bed.	Effluent from the Ragstone series. Secondary fine bed.	Effluent from the Coke series. Primary coarse bed.	Effluent from the Coke series. Secondary fine bed.
1898.						
Sept. 22	Once	4·412	4·759	5·000	4·759	1·471
23	,,	lost	4·510	4·412	4·608	0·784
26	,,	2·059	3·039	2·353	2·353	0·882
27	,,	2·330	2·718	2·524	2·718	0·777
28	,,	1·942	2·039	1·748	1·845	0·582
29	,,	2·600	2·500	1·900	2·700	0·600
30	,,	3·300	3·200	2·500	3·200	0·900
Oct. 3	,,	1·900	2·500	1·900	1·800	0·600
4	,,	2·200	2·300	1·800	1·900	0·600
5	,,	2·300	2·800	1·900	2·100	0·500
6	,,	1·800	1·800	1·400	1·400	0·600
7	,,	1·800	1·800	1·400	1·400	0·700
8	,,	2·200	2·300	2·000	1·700	0·700
10	,,	1·500	1·500	1·800	1·700	0·900
11	,,	3·000	2·800	1·900	2·600	1·100
12	,,	2·000	1·900	1·600	1·800	0·800
13	,,	1·700	1·600	1·300	1·500	0·700
14	,,	1·800	1·700	1·200	1·700	0·700
15	,,	2·700	2·600	2·000	2·500	1·100
17	,,	1·400	1·500	1·300	1·400	0·800
18	,,	2·200	1·800	1·600	1·800	0·900
19	,,	1·881	1·980	1·881	1·881	1·089
21	,,	3·267	3·168	1·782	3·168	1·188
22	,,	2·178	1·683	1·386	1·980	0·792
24	,,	2·673	2·376	1·584	2·178	0·891
25	,,	2·475	1·881	1·584	2·079	1·089
26	,,	3·069	2·376	1·485	2·178	0·792
27	,,	3·564	2·970	1·881	2·772	1·188
28	,,	4·059	3·366	2·277	3·069	1·584
29	,,	2·475	2·277	1·584	2·178	0·990
Nov. 2	,,	4·158	3·168	2·277	3·366	1·386
3	,,	4·059	3·366	1·782	3·069	1·287
4	,,	3·564	2·772	1·485	2·574	1·584
5	,,	4·275	3·366	2·277	3·267	1·287
7	,,	3·366	2·970	1·782	3·267	1·386
8	,,	3·960	3·168	1·881	3·168	1·287
9	,,	3·663	3·267	1·980	3·069	1·881
10	,,	3·564	2·970	1·980	2·871	1·584
11	,,	3·663	3·162	1·782	3·069	1·386
12	,,	4·356	3·465	2·376	3·366	2·079
14	,,	3·069	2·871	1·881	2·673	1·287
15	,,	4·554	3·069	1·980	2·673	1·485
16	,,	4·158	2·970	1·386	2·673	1·683
17	,,	4·158	3·168	1·782	3·267	1·368
18	,,	4·554	3·069	1·881	3·069	1·980
19	,,	4·653	3·564	1·980	3·366	2·079
21	,,	4·000	3·500	2·000	3·300	1·400
22	,,	4·000	3·400	1·800	3·600	1·400
23	,,	4·800	3·600	2·000	3·500	1·600
24	,,	4·700	3·900	2·300	3·900	1·700
25	,,	4·800	3·500	2·100	4·000	1·500
26	,,	4·400	3·000	1·500	3·200	1·100
28	,,	4·100	3·000	1·900	3·000	1·500
29	,,	4·300	3·400	1·800	3·900	1·400
30	,,	6·000	3·500	2·500	3·600	1·900
Dec. 1	,,	4·300	3·400	2·800	3·500	2·100
2	,,	5·500	3·800	2·300	4·100	1·900

TABLE I.—(*continued*).

Date.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of— Crude sewage.	Effluent from the Ragstone series. Primary coarse bed.	Effluent from the Ragstone series. Secondary fine bed.	Effluent from the Coke series. Primary coarse bed.	Effluent from the Coke series. Secondary fine bed.
1898.						
Dec. 3	Once	5·400	3·200	2·500	3·500	1·900
5	,,	5·400	3·500	2·300	3·800	2·000
6	,,	4·800	3·500	1·800	3·800	1·500
7	,,	4·900	3·500	2·400	3·600	2·200
8	,,	3·000	2·000	1·500	2·500	1·100
9	,,	4·200	3·000	1·700	2·700	1·300
10	,,	4·400	3·200	2·000	2·700	lost.
14	,,	5·200	3·300	2·300	3·900	1·600
15	,,	5·000	3·100	2·200	2·700	1·600
16	,,	5·100	3·900	2·600	3·800	1·900
17	,,	5·000	3·100	1·700	3·000	1·600
20	,,	4·500	3·800	2·200	3·800	1·600
21	,,	5·100	4·000	2·200	3·500	1·500
22	,,	4·200	3·700	2·300	2·100	1·600
23	,,	4·600	3·200	2·400	3·100	1·900
24	,,	5·600	4·100	2·100	4·000	1·600
29	,,	4·400	3·000	1·800	3·200	1·300
30	,,	4·700	3·200	2·000	3·700	1·300
31	,,	5·500	3·500	2·300	3·500	1·400
1899.						
Jan. 2	,,	3·600	2·600	1·300	2·100	1·700
3	,,	4·802	3·627	2·353	3·725	1·569
4	,,	5·098	3·922	2·157	3·922	1·471
5	,,	4·800	3·300	2·000	3·300	1·600
6	,,	4·700	3·300	1·700	3·000	1·400
7	,,	5·100	3·200	1·800	3·500	1·600
9	,,	4·100	3·400	2·100	2·800	1·400
11	Twice	4·200	3·700	2·000	4·100	2·100
12	,,	3·100	2·700	1·700	3·000	1·200
13	,,	3·300	2·600	1·800	2·800	1·000
14	,,	2·500	2·000	1·500	2·000	1·000
16	,,	2·900	2·200	1·000	2·400	1·000
17	,,	3·000	2·400	1·400	2·500	1·900
18	,,	3·500	3·000	1·700	3·000	1·100
19	,,	3·100	2·800	1·700	2·500	1·200
20	,,	4·200	3·400	2·200	2·900	1·100
21	,,	2·600	2·300	1·600	2·200	1·300
25	,,	4·158	3·366	1·980	3·168	1·485
26	,,	4·100	3·200	2·000	2·800	1·500
27	,,	3·700	3·200	1·700	3·000	1·500
28	,,	3·500	2·700	1·700	1·600	1·300
30	,,	3·500	3·100	1·900	2·700	1·400
31	,,	4·400	3·300	1·800	3·300	1·400
Feb. 1	,,	4·200	3·400	2·200	3·300	1·600
2	,,	4·000	2·700	2·600	3·300	1·500
3	,,	4·000	3·400	1·900	3·500	1·400
4	,,	3·000	2·700	1·800	2·500	1·400
6	,,	3·400	2·800	1·600	2·600	2·100
7	,,	2·900	2·300	1·500	2·200	1·300
8	,,	3·100	2·500	1·500	2·400	1·200
9	,,	3·100	2·600	1·500	2·300	1·200
10	,,	3·300	2·400	1·400	2·100	1·300
11	,,	3·500	3·300	1·600	3·100	1·400
13	,,	2·700	2·000	1·700	2·200	1·300
14	,,	3·000	2·600	1·800	2·300	1·500
15	,,	4·000	3·000	1·900	3·100	1·500
16	,,	3·200	2·700	1·700	2·700	1·500
17	,,	3·700	2·900	1·600	2·900	1·300
18	,,	3·300	2·500	1·700	2·600	1·300
20	,,	3·400	3·000	1·700	3·100	1·300
21	,,	3·900	3·000	1·700	3·100	1·500
22	,,	4·400	3·000	2·000	3·000	1·500
23	,,	4·400	3·500	1·900	3·300	1·600
24	,,	4·700	3·600	2·100	3·700	1·700
25	,,	3·700	3·400	2·000	3·000	1·700
27	,,	3·700	3·000	1·700	3·000	1·500
28	,,	4·600	3·100	1·900	3·100	1·500
Mar. 1	,,	4·300	2·900	1·800	2·800	1·300
4	,,	3·500	2·600	1·900	2·900	1·500

TABLE I.—(*continued*).

Date.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of— Crude sewage.	Effluent from the Ragstone series. Primary coarse bed.	Effluent from the Ragstone series. Secondary fine bed.	Effluent from the Coke series. Primary coarse bed.	Effluent from the Coke series. Secondary fine bed.
1898.						
Mar. 6	Twice	4·000	2·900	1·800	3·000	1·500
7	"	4·300	3·100	1·900	2·900	1·400
8	"	4·500	3·300	2·000	3·100	1·500
9	"	5·100	3·800	2·200	3·900	1·700
10	"	4·700	3·400	2·100	3·300	1·900
11	"	3·800	3·000	1·900	3·100	1·600
13	"	4·216	3·725	1·863	3·627	1·863
14	"	4·412	3·627	2·157	3·529	1·863
15	"	4·216	3·137	2·255	2·941	1·863
16	"	4·706	3·431	2·255	3·235	1·667
17	"	4·314	3·235	2·059	3·333	1·863
18	"	3·725	2·950	2·059	2·745	1·373
20	"	4·314	3·333	1·863	3·333	1·569
21	"	4·623	3·585	1·981	3·396	1·698
22	"	4·623	3·208	2·264	3·113	1·981
23	"	4·057	2·925	1·604	2·736	1·415
24	"	4·434	2·925	1·887	3·019	1·604
25	"	4·057	3·396	2·170	3·775	1·604
27	"	4·623	3·679	2·075	3·775	1·604
28	"	4·528	3·491	2·170	2·830	1·698
29	"	5·189	3·775	1·698	3 302	1·887
Apl. 5	"	5·094	4·717	2·736	5·000	1·792
6	"	4·057	3·208	2·547	3·208	1·509
7	"	3·868	3·396	2·075	3·019	1·321
8	"	4·151	3·585	1·792	3·585	1·604
10	"	2·925	2·264	1·415	2·547	1·321
11	"	3·208	2·359	1·604	2·736	1·321
12	"	4·057	3·019	1·887	2·736	1·509
13	"	3·775	3·019	1·698	2·925	1·415
14	"	2·736	2·170	1·415	2·359	1·321
15	"	2·830	2·547	1·604	2·547	1·226
Averages		3·797	3·015	1·933	2·944	1·396

TABLE 2.—TEMPERATURE READINGS OF THE ATMOSPHERE AND OF THE EFFLUENTS FROM THE COKE-BEDS OF SERIES A. AND B.

Temperatures in degrees Fahrenheit.

Date.	Air.	Crude sewage.	Air.	Effluent from primary bed A.	Effluent from primary bed B.	Air.	Effluent from secondary bed A 1.	Effluent from secondary bed B 1.
1899.								
Dec. 11	33·0	53·0	30·5	48·0	43·0	29·0	40·0	38·0
12	34·0	54·5	34·0	42·0	40·5	32·0	40·0	39·5
12	33·5	55·0	36·0	47·0	42·0	36·0	43·0	40·0
13	32·0	54·0	32·0	42·0	40·0	30·0	42·5	41·0
14	32·0	54·5	36·5	45·5	42·0	34·0	42·5	39·5
15	35·0	54·0	35·0	44·0	42·0	30·5	43·5	39·0
15	32·0	55·0	30·5	45·0	45·5	32·0	42·5	40·5
16	32·0	55·0	32·0	41·0	40·0	30·0	42·5	41·0
16	44·0	52·0	35·0	43·0	41·5	35·0	43·0	41·5
18	43·0	54·0	40·0	44·0	44·0	41·0	42·0	41·0
19	42·0	53·0	41·0	45·0	45·0	35·0	44·0	44·0
20	40·0	53·0	40·0	47·0	46·0	39·0	45·0	44·0
21	41·0	54·0	39·0	47·0	46·0	40·0	44·0	45·0
27	34·5	53·5	33·0	44·5	41·5	34·5	41·5	40·0
28	30·0	53·0	34·0	44·0	42·0	36·0	39·0	38·0
28	43·0	52·0	43·5	46·0	45·5	46·0	43·5	43·0
29	47·0	50·0	47·0	50·0	49·0	51·0	46·0	46·0
29	52·5	48·0	50·0	51·0	51·5	49·0	51·0	51·0
30	46·0	53·0	46·5	52·0	52·0	47·5	50·0	50·0
30	45·0	53·0	44·0	51·0	51·0	45·0	51·0	50·5
Averages	38·5	53·0	38·0	46·0	44·5	37·5	44·0	42·5

Table 3.—Temperature Readings of the Atmosphere, of the Crude Sewage, of the Effluents from the Coke-beds and of the Interior of the Coke-beds of Series A. and B.

Temperatures in degrees Fahrenheit.

Date.	Air.	Crude sewage.	Air.	Primary beds.			Air.	Secondary beds.		
				Interior of bed A.	Effluent from bed A.	Effluent from bed B.		Interior of bed A 1.	Effluent from bed A 1.	Effluent from bed B 1.
1900										
Jan. 22... ...	51·0	49·0	52·5	53·5	57·0	57·0	53·5	50·0	53·5	54·5
23... ...	53·5	52·5	52·0	54·5	52·5	52·0	52·5	52·0	52·5	52·0
24... ...	52·0	53·5	50·0	59·0	52·5	53·5	50·0	59·0	52·0	52·0
24... ...	57·0	53·5	52·5	57·0	54·5	53·5	47·5	53·5	52·0	50·0
25... ...	53·5	48·0	53·5	53·5	50·0	51·0	44·5	53·5	50·0	48·0
25... ...	57·0	52·0	49·0	57·0	52·0	52·0	50·0	55·0	52·0	52·5
26... ...	49·0	53·5	48·0	52·5	52·0	51·0	48·0	59·0	52·0	50·0
26... ...	52·0	53·5	52·5	53·5	53·5	52·5	49·0	55·5	51·0	51·0
27... ...	53·5	53·5	52·5	54·5	51·0	51·0	39·0	52·5	50·0	50·0
29... ...	41·0	50·0	48·0	50·0	52·0	51·0	48·0	50·0	52·0	52·0
30... ...	46·5	51·0	48·0	46·5	47·5	46·5	37·5	46·5	43·0	43·0
30... ...	41·0	51·0	30·0	50·0	44·5	44·5	39·0	41·0	43·0	43·0
31... ...	40·0	48·0	43·0	41·0	44·5	43·0	48·0	42·0	47·0	46·5
31... ...	43·0	52·0	43·0	53·5	44·5	44·5	42·0	53·5	44·0	44·5
Feb. 1... ...	44·5	51·0	37·5	48·0	40·0	41·0	34·0	37·5	41·0	41·0
1... ...	37·5	51·0	37·5	52·0	42·0	42·0	38·0	50·0	43·0	43·0
2... ...	34·0	50·0	35·5	48·0	44·5	46·0	34·0	39·0	41·0	41·0
2... ...	35·5	50·0	36·5	51·0	41·0	41·0	34·5	50·0	42·0	42·0
5... ...	46·5	50 0	44·5	48·0	40·0	41·0	37·5	48·0	40·0	39·0
6... ...	37·5	48·0	35·5	50 0	41·0	41·0	35·5	48·0	39·0	40·0
6... ...	40·0	48·0	36·5	47·0	44·5	44·5	34·0	41·0	40·0	40·0
8... ...	30·0	50·0	28·5	47·0	39·0	39·0	25·0	43·0	37·5	39·0
8... ...	36·5	48·0	34·0	48·0	40·0	40·0	35·5	37·5	37·5	36·5
9... ...	36·5	48·0	34·5	48·0	41·0	39·0	34·5	36·5	39·0	37·5
10... ...	26·5	50·0	26·5	47 0	39·0	39·0	37·5	45·5	39·0	38·0
10... ...	37·5	48·0	36·5	48·0	41·0	39·0	35·5	44·5	41·0	39·0
Averages ...	43·5	50·5	42·0	50·5	46·0	46·0	41·0	48·0	45·0	45·0

Table 4.—Percentage Composition of the Air at the Bottom of the Primary Coke-bed B.

Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.	Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.
1899.				1899.			
Oct. 19	22	1·6	17·4	Nov. 17	17	8·0	10·5
20	20	3·0	15·6	20	68	2·0	16·4
23	19	4·2	14·8	21	17	4·0	15·0
24	19	8·8	4·0	22	17	6·0	12·4
25	19	11·4	1·4	23	19	8·0	12·1
28	43	8·0	6·4	24	19	7·6	12·2
31	19	4·0	9·0	28	19	8·6	6·0
Nov. 1	19	5·0	7·4	29	19	7·6	6·4
2	20	4·0	10·0	Dec. 1	19	8·8	3·2
3	20	3·6	9·8	5	19	7·5	6·1
4	38	3·6	10·2	7	19	8·8	3·0
6	19	7·0	8·2	8	19	4·0	13·0
7	19	8·6	4·2	12	19	5·8	11·8
9	19	4·0	16·0	13	19	5·0	11·8
10	16½	5·0	13·6	14	19	7·2	10·2
13	67	1·2	18·2	19	4	6·0	5·0
14	17	3·0	15·0	20	4	7·0	5·0
15	17	3·6	15·2	21	4	8·0	4·2
16	17	4·0	15·6	22	4	2·4	13·6
				Averages	21	5·7	10·3

In pure atmospheric air the average percentage of carbon dioxide is 0·04, and of oxygen 20·96.

TABLE 4.—(*continued*).

Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.	Date.	Number of hours bed stood empty.	Percentage of carbon dioxide.	Percentage of oxygen.
1900.				1900.			
Jan. 2	4	7·8	5·8	Jan. 23	4	5·4	9·4
3	4	9·9	3·9	25	4	6·4	6·4
4	4	1·8	17·2	26	4	5·2	10·8
9	4	7·0	9·8	30	4	4·6	5·4
10	4	6·9	7·7	Feb. 1	4	3·6	10·4
11	4	7·8	3·6	2	4	3·4	9·8
12	4	5·6	8·4	6	4	5·4	8·2
16	4	6·0	4·9	8	4	7·0	8·0
17	4	4·7	7·9	9	4	4·0	9·8
18	4	2·8	11·2	22	4	6·4	8·0
19	24	6·6	3·4	23	4	7·8	5·6
				Averages	5	5·7	8·0

In pure atmospheric air the average percentage of carbon dioxide is 0·04, and of oxygen 20·96.

TABLE 5.—AMOUNT OF NITRIFICATION PRODUCED IN THE COKE BEDS OF SERIES A AND B.

Date.	Nitrogen as Nitrite in					Nitrogen as Nitrate in				
	Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.		Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.	
		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed.	Secondary Fine Bed.		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed	Secondary Fine Bed.
1899.										
July 4	Nil	Nil	Nil	Nil	0·1400	0·1306	0·1325	0·1306	0·1625	0·3387
5	,,	,,	,,	,,	0·1750	0·0618	0·0850	0·0556	0·0368	1·1900
6	,,	,,	,,	,,	0·2450	0·0837	0·2281	0·0975	0·2206	0·8625
7	,,	,,	,,	,,	0·2450	0·1162	0·1012	0·0587	0·0381	0·9818
8	Slight trace	,,	,,	,,	0·2800	0·1437	0·0662	0·1075	0·1056	0·2587
11	Nil	,,	,,	,,	0·2520	0·0612	0·0506	0·0719	0·1106	1·7305
12	,,	,,	,,	,,	0·1610	0·1925	0·0762	0·2125	0·1350	1·1915
13	,,	,,	,,	,,	0·0280	0·1306	0·1987	0·1468	0·1481	1·9176
14	,,	,,	,,	,,	0·0308	0·1356	0·1662	0·1218	0·1450	2·2761
15	,,	,,	,,	,,	0·1050	0·0837	0·1444	0·2687	0·1906	1·6294
17	,,	,,	,,	,,	0·0140	0·1112	0·2232	0·0319	0·0969	2·0956
19	,,	,,	0·1190	,,	0·0250	0·0275	0·0294	Nil	0·1181	1·9387
21	,,	0·0280	Nil	,,	0·0210	Trace	0·1032	Trace	0·0362	1·6415
24	,,	0·1050	0·4480	,,	0·0393	0·1207	0·1970	0·1980	0·1206	1·2217
26	,,	0·0140	0·3150	,,	0·0336	0·1530	0·1240	0·1670	0·1789	1·2284
28	,,	Nil	0·2100	,,	0·0420	0·1181	0·4385	0·4087	0·1856	1·1950
31	,,	0·0182	0·2100	,,	0·0532	0·1201	0·4528	0·4781	0·1800	0·0668
Aug. 2	,,	0·0210	0·2100	,,	0·0420	0·0856	0·0979	0·3762	0·1775	1·2640
4	,,	Nil	0·2100	,,	0·0140	0·0468	0·0701	0·3881	0·0726	1·4300
9	,,	0·3780	0·0420	0·2100	0·0210	0·0357	0·5166	1·1650	0·0910	1·7470
11	,,	0·2800	0·0560	Nil	0·0350	0·2410	0·2001	0·9195	0·4770	2·3400
14	,,	0·2800	0·0560	,,	0·0350	0·1493	0·2600	0·8460	0·1756	1·9540
16	,,	0·2800	0·0700	,,	0·0420	0·2947	0·0395	1·7570	0·2365	1·8700
18	,,	0·1400	0·0600	,,	0·0280	0·2370	0·4627	1·6370	0·2425	1·6690
21	,,	0·0560	0·0420	,,	0·0280	0·1815	0·1822	1·1660	0·1815	1·3160
23	,,	0·0140	0·1400	,,	0·0140	0·2426	0·0548	1·8806	0·2415	1·8400
25	,,	0·0140	0·1400	,,	0·0350	0·3566	0·3413	1·0840	0·3623	1·8650
28	,,	0·1736	0·0582	0·2100	0·0210	0·0618	0·9054	1·1828	1·1050	2·4650
30	,,	0·3500	0·1050	0·2800	Nil	0·4818	1·0970	1·5950	0·2000	1·8120
Sept. 1	,,	0·2800	0·0350	0·0252	,,	0·1703	0·5665	0·1986	2·0760	0·8441
4	,,	0·2100	0·0420	0·0210	,,	0·1156	1·7780	2·4400	0·4748	1·6160
6	,,	0·2800	0·1050	Nil	0·0280	0·1818	0·9230	1·5230	0·1794	1·7150
8	,,	0·0210	0·1400	,,	0·0420	0·3578	0·4000	1·8620	0·3586	1·8350
11	,,	0·2800	0·1400	0·2100	0·0210	0·0981	0·1968	0·7500	0·2760	0·5852
13	,,	0·2800	0·0280	0·2100	0·0140	0·0903	0·4498	1·9425	0·1105	2·3566
15	,,	0·0840	0·0490	0·0140	0·0350	0·1325	0·5956	1·2853	0·3375	2·6590
18	,,	0·0252	0·0840	0·0420	0·0280	0·1161	0·5621	1·3990	1·1670	1·9730
21	,,	0·2100	0·0280	0·0210	0·0280	0·2336	0·3773	0·7260	0·0560	0·7420
22	,,	0·2800	0·0560	0·3500	0·0420	0·1580	0·7003	1·0400	0·6510	1·6660
23	,,	0·0140	0·2100	0·0140	0·0128	0·1903	0·2214	0·6418	0·3952	1·5672
25	,,	0·0210	0·2100	0·0182	0·0280	0·2351	0·6871	0·7911	0·7524	2·0630
26	,,	0·0140	0·0420	0·0140	0·0210	0·1480	0·2977	0·9201	0·5899	1·4400
27	,,	0·0210	0·1400	0·0210	0·0280	0·3623	0·6965	0·9431	0·4631	1·6526
28	,,	0·0210	0·0280	0·0182	0·0252	0·2545	1·0738	1·2991	0·6953	0·8778
29	,,	0·0210	0·0420	0·0210	0·0182	0·2953	1·1630	1·2600	0·5673	1·4048

TABLE 5.—(*continued*).

Date.	Nitrogen as Nitrite in					Nitrogen as Nitrate in				
	Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.		Crude sewage.	Coke-beds of Series A.		Coke-beds of Series B.	
		Primary Coarse Bed.	Secondary Coarse Bed.	Primary Coarse Bed.	Secondary Fine Bed.		Primary Coarse Bed.	Secondary Coarse Bed	Primary Coarse Bed	Secondary Fine Bed.
1899.										
Oct. 2	Nil.	0·2100	0·0560	0·1820	0·0182	0·2431	1·0343	1·5156	1·0412	0·6947
3	„	0·1680	0·0420	0·5600	0·0140	0·3503	1·9750	2·6961	0·9251	2·5524
4	„	0·1400	0·1120	0·2100	0·0210	0·3499	2·2200	2·3530	0·3931	2·0846
5	„	0·1400	0·0210	0·1260	0·0210	0·2053	1·3352	1·0798	2·3817	1·4421
6	„	0·1400	0·0210	0·0820	Nil	0·4218	2·1900	2·2350	2·1775	2·2500
7	„	0·0210	0·2800	0·0210	0·0280	0·3691	0·7216	0·9792	0·4841	1·5577
13	„	0·1400	0·0210	0·2100	0·0140	0·2441	1·4467	2·1194	0·8775	1·1940
14	„	0·0182	0·7000	Nil	0·0210	0·2317	1·8474	1·7881	0·8274	1·0501
16	„	0·0420	0·0280	0·0350	Nil	0·2978	1·2051	1·8431	1·3311	1·5583
17	„	0·0630	0·0280	0·1400	0·0140	0·3559	1·1960	0·9313	1·1892	0·9594
18	„	0·0210	0·0420	0·0560	0·0140	0·1810	0·2205	0·7604	0·2456	1·7178
19	„	0·1120	0·0280	0·0840	0·0140	0·2046	0·2530	1·0307	0·1188	3·0485
20	„	0·1400	0·0210	0·1120	0·0182	0·2270	0·1693	0·9627	0·4228	2·8098
21	„	0·0140	0·1400	0·0140	0·0350	0·2263	0·2289	0·5935	0·2289	1·8477
23	„	0·0210	0·0420	0·0140	0·0210	0·2399	0·4105	0·7126	0·2955	1·6935
24	„	0·0210	0·0280	0·0210	0·0280	0·2421	0·3438	0·8054	0·2760	2·1342
25	„	0·0140	0·0700	0·0210	0·0350	0·0847	0·2280	0·8907	0·2282	2·3750
26	„	0·1820	0·0280	0·0182	0·0420	0·1070	0·2196	0·9457	0·2834	1·6542
28	„	0·0140	0·0560	0·0140	0·0350	0·0799	0·1653	0·3533	0·2135	0·9708
30	„	0·0350	0·0140	0·0280	0·0140	0·0540	0·5816	1·2142	0·0773	1·5827
31	„	0·1120	0·0140	0·0210	Nil	0·0607	0·0093	0·4858	0·1661	1·6225
Nov. 1	„	0·0280	0·0182	0·0560	0·0140	0·3073	1·0840	1·4178	1·1350	1·9972
2	„	0·0140	0·0420	0·0140	0·0140	0·1791	0·2824	1·4140	0·1627	1·5766
3	„	0·1820	0·0700	0·0140	Nil	0·1199	0·1513	0·8537	0·2941	2·1005
4	„	0·0210	0·0280	0·0840	0·0140	0·0623	0·4766	1·2141	0·1023	2·2298
6	0·280	0·1400	0·0210	0·1120	Nil	0·4670	1·1637	1·9533	0·7517	2·2690
7	Nil	0·1400	0·0280	0·1400	0·0140	0·0593	0·6595	1·3960	0·4718	2·0730
8	„	0·1400	0·0280	0·1400	Nil	0·0585	0·5250	1·2161	0·2343	1·7410
9	„	0·2100	0·0560	0·1400	0·0182	0·2452	0·1681	0·9638	0·1661	1·6943
10	„	0·2100	0·0420	0·2800	Nil	0·1215	0·5209	1·7887	0·3290	1·7000
13	„	0·1400	0·0280	0·1400	0·0210	0·0603	0·5974	1·4260	0·5656	2·3280
14	„	0·2100	0·0420	0·2100	0·0280	0·1245	0·1531	1·6210	0·4025	1·8100
15	„	0·2100	0·0350	0·1400	0·0210	0·1837	0·1610	1·2037	0·3513	2·4100
16	„	0·2100	0·0350	0·2100	0·0210	0·2240	0·0140	0·6250	0·1666	1·9890
17	„	0·2100	0·0420	0·1400	0·0560	0·0549	0·1575	0·9620	0·0458	1·5620
18	„	0·0560	0·1400	0·0280	0·0560	Trace	0·2165	0·7337	0·1570	1·6520
20	„	0·2800	0·0420	0·2800	0·0280	0·0596	0·1738	1·3190	0·1469	2·8720
21	„	0·2100	0·0420	0·2100	0·0210	0·1212	0·5291	1·2992	0·0338	2·6660
22	„	0·0420	0·0560	0·0840	0·0420	0·0579	0·1036	1·0973	0·0616	2·3630
23	„	0·0700	0·0420	0·0280	0·1400	0·1813	0·5311	1·1513	0·2456	1·9016
24	„	0·0560	0·0420	0·0420	0·1400	0·1829	0·2520	0·8115	0·2545	1·6421
25	0·0140	0·0560	0·1680	0·0280	0·0560	0·0448	0·1792	0·2734	0·1754	1·1978
27	Nil	0·0210	0·0420	0·0140	0·0420	0·0605	0·0700	0·8155	0·0485	0·9348
28	„	0·1190	0·0490	0·0252	0·0560	0·1168	0·0066	1·3603	0·1023	0·0721
29	0·0140	0·0280	0·0378	0·0182	0·0378	0·0472	0·1132	1·3684	0·1043	0·2153
30	0·0140	0·1820	0·0280	0·0322	0·0322	0·0466	Lost	1·3570	0·1184	1·5303
Dec. 1	Nil	0·0700	0·0840	0·0140	0·0350	0·1203	0·7335	0·6685	0·1090	1·9817
2	„	0·0280	0·2100	0·0210	0·0700	0·1202	0·2118	0·6193	0·1601	1·6980
4	0·0280	0·2100	0·0280	0·0280	0·0280	0·2138	0·2211	1·4407	0·2188	2·0555
5	Nil	0·2100	0·0840	0·0210	0·0420	Nil	0·2878	1·1028	0·1604	2·4463
7	„	0·0210	0·0280	0·0140	0·0210	0·1198	0·1588	0·4693	0·2930	0·8491
8	„	0·0280	0·0210	0·0210	0·0140	0·2420	0·5795	1·2933	0·2210	1·6136
9	„	0·0420	0·1400	0·3500	0·0210	Trace	0·1980	0·7150	0·0116	1·5865
11	„	0·0140	0·0210	0·0420	0·0420	0·2379	0·2965	1·2190	0·3304	1·5128
12	„	0·0280	0·1400	0·0420	0·0210	0·3688	0·7131	0·7201	0·5714	1·8435
13	„	0·0280	0·0560	0·0280	0·0140	0·1758	0·1478	0·5560	0·1930	1·3376
14	„	0·1400	0·0280	0·0280	0·0210	0·2450	0·2192	0·2312	0·0912	1·2240
15	„	0·0210	0·0560	0·0210	0·0210	0·0622	0·1255	0·3023	0·2913	0·8119
16	„	0·0210	0·2100	0·0210	0·1400	0·2333	0·3916	0·3881	0·2258	0·5645
18	„	0·1400	0·0280	0·1400	0·0420	0·1196	0·2203	0·5663	0·0390	1·3278
19	„	0·1050	0·1050	0·0420	0·0420	0·0595	0·4968	0·6138	0·1998	1·2833
20	„	0·0420	0·2100	0·0280	0·0420	0·0606	0·1401	0·1228	0·2123	1·1573
21	0·0420	0·0280	0·1400	0·0280	0·0420	0·0173	0·1523	0·1627	0·3317	0·2553
22	Nil	0·0140	0·0280	0·0280	Nil	0·1001	0·1868	0·3335	0·2113	1·0656
27	0·0560	0·0840	0·0210	0·0560	0·0210	0·0612	0·0360	0·6992	0·0475	1·2004
28	Nil	0·0560	0·0210	0·0140	0·0140	0·0571	0·1224	0·4473	0·2210	1·2403
29	„	0·0210	0·0420	0·0140	0·0280	0·1129	0·3213	0·5370	0·2719	1·2833
30	„	0·0140	0·1050	0·0140	0·0420	0·0611	0·1266	0·1303	0·1019	1·2325
Averages	0·004	0·0932	0·0767	0·0645	0·0409	0·1602	0·4474	0·9279	0·3562	1·5861

It is worthy of note that after the beds had rested on Sundays an increased amount of nitrate was found in the Monday effluent. There can be little doubt that this additional nitrate was produced during the Sunday's rest, and was washed by the first effluent after the period of rest. This result was specially marked in the case of the secondary beds.

Table 6.—Number of times the Coke-beds of Series A and B were filled each day, and the amount of Oxygen absorbed by the Crude Sewage and by the corresponding Coke-bed Effluents.

Date, 1899.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in four hours by one gallon of				
		Crude sewage.	Effluent from series A.		Effluent from series B.	
			Primary coarse bed.	Secondary coarse bed.	Primary coarse bed.	Secondary fine bed.
July 4th ...	Once	4·712	2·971	1·827	2·692	0·769
,, 5th ...	,, ...	4·615	3·269	1·827	2·596	0·865
,, 6th ...	,, ...	3·846	2·885	1·731	2·500	0·865
,, 7th ...	,, ...	4·135	2·500	1·731	2·692	0·769
,, 8th ...	,, ...	3·942	2·404	1·635	2·500	0·672
,, 11th ...	,, ...	3·750	3·077	2·115	2·212	0·769
,, 12th ...	,, ...	4·327	2·971	1·731	3·269	0·500
,, 13th ...	,, ...	4·327	2·692	1·635	2·971	0·672
,, 14th ...	,, ...	3·942	2·971	1·731	3·077	0·577
,, 15th ...	,, ...	4·423	2·596	1·346	2·692	0·672
,, 17th ...	,, ...	4·190	2·571	1·714	2·762	0·762
,, 19th ...	,, ...	4·476	2·857	2·857	2·952	1·909
,, 21st ...	,, ...	3·714	1·619	0·857	1·428	0·857
,, 24th ...	,, ...	3·908	2·285	1·809	2·476	0·761
,, 26th ...	,, ...	3·789	1·684	1·684	2·526	0·438
,, 28th ...	,, ...	4·210	2·315	1·263	2·241	0·438
,, 31st ...	,, ...	4·742	2·680	1·753	2·887	0·825
August 2nd ...	,, ...	3·918	2·268	1·649	2·474	0·722
,, 4th ...	,, ...	4·330	2·680	1·856	2·680	0·825
,, 9th ...	,, ...	3·196	2·577	1·237	2·577	0·825
,, 11th ...	,, ...	3·228	2·187	1·237	1·666	0·833
,, 14th ...	,, ...	4·700	2·800	1·500	2·600	0·700
,, 16th ...	,, ...	4·100	2·800	1·900	2·800	0·800
,, 18th ...	,, ...	3·600	2·000	2·300	2·100	0·800
,, 21st ...	,, ...	4·791	2·400	1·562	2·500	0·937
,, 23rd ...	,, ...	4·583	2·604	1·354	2·604	1·041
,, 25th ...	,, ...	4·791	2·500	1·458	2·291	1·145
,, 28th ...	,, ...	2·688	2·043	1·387	2·150	0·968
,, 30th ...	,, ...	3·978	2·258	1·387	2·043	0·860
September 1st...	,, ...	4·387	2·427	2·142	1·436	1·020
,, 4th...	,, ...	4·842	1·474	0·737	2·526	0·947
,, 6th...	,, ...	4·687	2·812	1·875	2·708	0·937
,, 8th...	,, ...	4·787	1·809	1·596	2·553	0·957
,, 11th...	,, ...	4·105	2·842	1·684	2·421	0·947
,, 13th...	,, ...	5·263	2·421	1·474	2·526	0·947
,, 15th...	,, ...	4·255	2·340	1·489	2·234	0·745
,, 18th...	,, ...	4·680	2·659	1·170	2·234	0·851
,, 21st...	,, ...	4·680	3·085	1·255	2·125	1·170
,, 22nd...	,, ...	4·255	1·595	1·276	1·702	0·744
,, 23rd...	,, ...	4·042	1·595	1·489	1·489	0·851
,, 25th...	,, ...	4·361	2·659	1·808	2·659	0·744
,, 26th...	,, ...	4·255	2·453	1·489	2·125	0·957
,, 27th...	,, ...	4·680	3·085	1·914	2·659	1·255
,, 28th...	,, ...	4·479	2·708	1·770	2·604	1·250
,, 29th...	,, ...	4·583	2·916	1·770	2·812	1·458
October 2nd ...	,, ...	4·895	3·541	1·979	3·854	0·833
,, 3rd ...	,, ...	4·631	1·786	1·489	2·812	0·947
,, 4th ...	,, ...	4·315	2·812	1·894	3·368	1·263
,, 5th ...	,, ...	4·631	2·659	1·474	2·812	1·157
,, 6th ...	,, ...	4·631	2·526	1·489	2·000	0·947
,, 7th ...	,, ...	3·568	2·421	1·894	2·812	0·842
,, 13th ...	,, ...	4·903	2·500	1·634	3·076	1·153
,, 14th ...	,, ...	4·903	2·798	2·692	2·980	0·865
,, 16th ...	,, ...	3·173	1·923	1·346	1·538	0·961
,, 17th ...	,, ...	4·615	2·403	1·826	2·596	0·961
,, 18th ...	,, ...	4·444	2·500	1·730	2·403	1·153
,, 19th ...	,, ...	4·653	1·584	0·990	2·277	0·990

TABLE 6.—(*continued*).

Date, 1899.	Number of times filled daily.	Number of grains of oxygen absorbed from permanganate in 4 hours by one gallon of—				
		Crude sewage.	Effluent from series A.		Effluent from series B.	
			Primary course bed.	Secondary coarse bed.	Primary coarse bed.	Secondary fine bed.
October 20th ...	Once	3·861	2·178	1·287	1 584	0·792
„ 21st ...	„	4·059	1·881	1·386	2·574	0·990
„ 23rd ...	„	4·215	2·745	1·764	2·352	0·980
„ 24th ...	„	4·313	2·549	1·470	2·549	1·078
„ 25th ...	„	4·411	2·549	1·764	2·451	0·980
„ 26th ...	„	4·411	2·156	1·078	2·647	0·980
„ 28th ...	„	3·235	1·764	1·372	2·254	0·784
„ 30th ...	„	2·843	1·470	0·892	1·274	0·588
„ 31st ...	„	4·803	2·352	1·372	2·156	0·882
November 1st ...	„	4·509	1·961	1·176	2·254	0·882
„ 2nd ...	„	5·294	2·843	1·764	2·352	0·980
„ 3rd ...	„	4·313	2·745	1·570	1·961	0·882
„ 4th ...	„	1·764	1·274	0·882	1·078	0·588
„ 6th ...	„	2·156	1·176	0·784	1·078	0·686
„ 7th ...	„	3·431	1·860	1·176	1·764	0·882
„ 8th ...	„	2·941	1·570	1·372	1·078	0·588
„ 9th ...	„	4·216	2·254	1·470	2·156	0·980
„ 10th ...	„	2·843	1·863	1·078	1·667	0·686
„ 13th ...	„	2·745	1·667	1·078	1·470	0·882
„ 14th ...	„	4·803	2·745	1·372	2·156	1·078
„ 15th ...	„	4·000	2·300	1·800	2·100	0·900
„ 16th ...	„	4·400	2·700	1·300	2·200	1·100
„ 17th ...	„	4·900	2·600	1·600	2·300	1·000
„ 18th ...	„	4·100	3·400	1·800	2·500	0·900
„ 20th ...	„	4·400	2·500	1·900	2·400	0·900
„ 21st ...	„	4·117	2·352	1·568	2·745	0·882
„ 22nd ...	„	4·607	2·745	1·667	2·549	0·882
„ 23rd ...	„	4·215	2·254	1·372	2·254	1·274
„ 24th ...	„	5·000	2·156	2·058	2·549	1·372
„ 25th ...	„	4·059	2·277	1·386	2·277	1·089
„ 27th ...	„	4·950	3·366	2·376	3·366	1·584
„ 28th ...	„	7·100	1·500	1·600	2·500	1·300
„ 29th ...	„	5·500	3·200	1·900	3·400	1·600
„ 30th ...	„	4·500	2·200	1·700	2·800	1·200
December 1st ...	„	4·900	1·600	1·800	2·700	1·400
„ 2nd ...	„	4·100	2·200	1·700	2·400	1·300
„ 4th ...	„	5·000	3·000	2·000	2·900	1·200
„ 5th ...	„	5·100	3·000	1·900	3·100	1·500
„ 7th ...	„	4·653	2·574	1·683	2·772	1·287
„ 8th ...	„	5·148	2·178	1·584	2·178	1·386
„ 9th ...	„	4·300	2·500	1·700	2·300	1·200
„ 11th ...	Twice... ...	4·500	2·400	1·700	1·800	1·300
„ 12th ...	„	5·100	2·800	2·000	2·500	1·300
„ 13th ...	„	5·100	2·700	1·800	2·500	1·200
„ 14th ...	„	4·800	2·500	1·800	2·600	1·300
„ 15th ...	„	4·100	1·900	1·700	2·800	1·500
„ 16th ...	„	4·700	3·100	1·600	2·700	1·600
„ 18th ...	„	4·300	2·100	1·700	2·100	1·400
„ 19th ...	„	4·300	1·300	1·300	2·200	1·300
„ 20th ...	„	5·300	2·900	2·000	3·000	1·700
„ 21st ...	„	3·500	2·800	1·900	2·600	2·700
„ 22nd ...	„	5·600	2·800	2·100	3·100	1·600
„ 27th ...	„	4·700	3·300	1·700	2·700	1·600
„ 28th ...	„	4·500	2·400	1·800	2·400	1·200
„ 29th ...	„	4·900	2·500	2·000	3·400	1·500
„ 30th ...	„	3·200	2·200	1·600	2·100	1·000
	Averages ...	4·314	2·422	1·616	2·424	1·027

Tables 7.—Particulars of the Treatment of Sedimented Chemical Effluent in the One Acre Coke-Bed.

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1898.									
May 12	No record as regards total oxidisable matter.				No record as regards total oxidisable matter.				818,680
„ 13									743,341
„ 14									717,669
„ 16		2·871				0·564			748,903
„ 17		4·700				0·844			705,782
„ 18		4·100				0·917			732,699
„ 19		2·500				0·531			702,605
„ 20		2·100				0·469			719,532
„ 21		2·300				0·469			695,500
„ 23		2·700				0·569			695,500
„ 25		3·000	Nil	0·0029		0·520	0·0280	0·0873	749,000
„ 26		3·300	„	0·0017		0·630	0·1050	Nil	695,500
„ 27		2·100	„	0·0059		0·480	0·0140	0·2166	722,250
„ 28									722,250
„ 31									749,000
June 1		2·600	„	0·0170		0·480	0·0210	0·0943	722,250
„ 2		2·500	„	0·0115		0·460	0·0140	0·0780	703,161
„ 3		2·500	„	0·0173		0·470	0·0182	0·0971	722,250
„ 4		2·200	„	Nil		0·480	0·0210	0·1058	722,250
„ 6		2·800	„	„		0·470	0·0140	0·1013	728,274
„ 7		3·600	„	0·0115		0·690	0·0140	0·1186	722,250
„ 8		2·800	„	Nil		0·540	0·0182	0·1086	712,205
„ 9		2·900	„	„		0·500	0·0210	0·1116	722,250
„ 10		3·000	„	„		0·471	0·0210	0·0943	722,250
„ 11		2·200	„	„		0·412	0·0210	0·2096	695,500
„ 13		2·900	„	„		0·519	0·0140	0·2570	722,250
„ 14		3·800	„	0·0217		0·577	0·0252	0·2342	678,048
„ 15		3·700	„	0·0115		0·663	0·0280	0·1450	678,048
„ 16		3·100	„	0·0173		0·620	0·0322	0·0716	668,750
„ 17		2·400	„	0·0115		0·490	0·0182	0·0738	668,750
„ 18		2·000	„	Nil		0·460	0·0350	0·0976	678,048
„ 20		2·300	„	„		0·510	0·0420	0·1136	695,500
„ 21		2·500	„	„		0·578	0·0280	0·1161	668,750
„ 22		2·900	„	0·0115		0·520	0·0280	0·0758	668,750
„ 23		2·800	„	0·0404		0·519	0·0210	0·0943	642,000
„ 24		2·600	„	Nil		0·500	0·0182	0·1374	605,553
„ 25		1·800	„	„		0·462	0·0210	0·0712	642,000
„ 27		2·500	„	„		0·481	0·0210	0·0655	668,750
„ 28		2·500	„	„		0·425	0·0210	0·0655	642,000
„ 29		2·800	„	„		0·453	0·0182	0·1893	642,000
„ 30		2·300	„	„		0·442	0·0210	0·1002	642,000
July 1		2·300	„	„		0·463	0·0210	0·1231	642,000
„ 2		1·600	„	„		0·505	0·0378	0·0948	642,000
„ 4		2·200	„	„		0·432	0·0210	0·0943	652,700
									642,000
„ 5		3·000	„	„		0·545	0·0518	0·0922	647,350
									642,000
„ 6		2·800	„	0·0461		0·596	0·0182	0·0692	642,000
									631,300
„ 7		3·100	„	Nil		0·667	0·0140	0·0494	628,658
									636,650
„ 8		3·000	„	„		0·657	0·0148	0·0601	642,000
									625,950
„ 9									642,000
									502,900
„ 11		3·500	„	0·0173		0·634	0·0182	0·0798	486,850
									466,667
„ 12		3·500	„	Nil		0·683	0·0322	0·1350	540,350
									460,287
„ 13		3·600	„	0·0230		0·677	0·0252	0·1477	632,177
									588,500
„ 14		3·400	„	0·0173		0·635	0·0196	0·0957	599,200
									588,500
„ 15		3·200	„	Nil		0·667	0·0210	0·0193	622,800
									593,850

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed. — Oxygen absorbed from permanganate in four hours. — By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrogen as — Nitrite.	Nitrate.	Coke-bed effluent. — Oxygen absorbed from permanganate in four hours. — By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrogen as — Nitrite.	Nitrate.	Quantity treated. Gallons.
1898.									
July 16		2·200	Nil	Nil		0·633	Trace	Nil	615,250 604,550
„ 18		1·700	„	„		0·571	0·0322	0·0139	615,250 587,330
„ 19		3·000	„	„		0·663	0·0350	0·0226	649,640 369,919
„ 20		2·500	„	„		0·633	0·0238	0·0742	406,600 620,326
„ 21		2·700	„	„		0·633	0·0182	0·0740	609,900 596,285
„ 22		2·276	„	„		0·630	0·0233	0·0511	612,755 571,982
„ 23		2·178	„	„		0·540	0·0168	0·0524	587,642 556,400
„ 25		3·069	„	0·0173		0·670	0·0238	0·0086	588,500 569,106
„ 26		3·960	„	Nil		0·720	0·0210	0·0230	561,750 540,671
„ 27		2·475	„	„		0·680	0·0210	0·0346	602,710 552,033
„ 28		2·574	„	0·0115		0·600	0·0168	0·0230	572,450 535,000
„ 29		3·366	„	Nil		0·570	0·0168	0·1326	572,450 508,250
Nov. 8	4·950	3·663	Nil	0·0987	1·089	0·649	0·1190	1·8129*	469,101
„ 9	4·950	3·762	„	0·2006	1·089	0·505	0·1190	0·8697	642,000
„ 10	4·950	3·366	„	0·1312	0·990	0·567	0·0700	0·7211	561,750
„ 11	7·921	3·010	„	0·0969	0·693	0·557	0·0560	0·5171	695,500
„ 12	4·950	3·366	„	0·1444	1·089	0·557	0·0840	0·2729	668,750
„ 14	3·960	3·564	„	0·0075	0·990	0·569	0·0182	0·7212	722,250
„ 15	4·950	3·960	„	0·0431	1·089	0·539	0·0182	0·6555	668,750
„ 16	4·950	3·663	„	0·0937	0·990	0·539	0·0210	0·5952	668,750
„ 17	3·960	3·465	„	0·1131	0·990	0·577	Trace	0·5562	668,750
„ 18	4·950	3·456	„	0·0525	0·891	0·547	Trace	0·4025	676,130
„ 19	5·000	3·500	„	0·2437	1·300	0·629	0·0160	0·2877	668,750
„ 21	5·000	4·000	„	0·0700	1·200	0·581	0·0140	0·7110	695,500 652,700
„ 22	7·000	5·300	0·0490	0·0829	1·200	0·619	0·0140	0·8385	625,950 642,003
„ 23	7·000	5·200	Trace	0·1094	0·700	0·619	0·0140	0·4347	636,650 631,300
„ 24	7·000	5·000	Nil	0·0244	1·500	0·707	0·0182	0·3687	597,562 615,250
„ 25	5·000	3·500	0·0350	Lost	1·200	0·535	0·0180	0·1937	674,100 636,650
„ 26	3·000	2·400	Nil	0·0375	0·900	0·510	0·0140	0·4754	636,650 631,300
„ 28	5·000	3·900	„	0·0687	1·000	0·570	0·0238	0·5549	663,400 615,250
„ 29	5·000	3·900	0·0350	Nil	0·800	0·520	0·0210	0·7065	603,253 609,900
„ 30	6·000	4·000	Nil	0·0237	1·100	0·627	0·0210	0·3396	615,250
Dec. 1	6·000	4·300	„	0·0806	1·000	0·529	0·0140	0·5672	688,618
„ 2	7·000	5·100	Trace	0·0319	1·100	0·559	0·0182	0·5593	655,228 630,810
„ 3	6·000	3·600	Nil	0·1362	1·300	0·618	0·0350	0·3394	574,927
„ 5	6·000	5·000	„	—	1·300	0·702	0·0210	—	642,000 608,964
„ 6	6·000	5·300	„	0·1606	1·200	0·635	0·0210	0·6415	642,000 603,252
„ 7	5·000	3·400	0·1190	0·0841	1·000	0·529	0·0252	0·7494	574,797 580,488

* This large amount of nitrate, as compared with that found on July 29th, had probably been produced during the period of resting, and was washed out in the first effluent.

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1898.									
Dec. 8	5·000	3·500	0·6300	Nil	1·100	0·551	0·0280	0·6420	574,797
									557,506
,, 9	4·000	3·800	0·0560	0·0221	0·800	0·551	0·0210	0·4690	605,676
									524,300
,, 10	4·000	3·800	Trace	0·0656	0·900	0·622	0·0280	0·3420	588,500
									583,150
,, 12	6·000	4·500	,,	0·0737	0·900	0·550	0·0210	0·7502	588,500
									540,350
,, 13	6·000	4·700	0·0140	Nil	1·200	0·640	0·0238	0·3468	540,651
,, 14	4·000	2·700	0·0490	,,	0·700	0·530	0·0210	0·4040	569,106
									552,033
,, 15	5·000	4·300	0·0420	,,	1·100	0·620	0·0238	0·2199	558,724
									567,100
,, 16	5·000	4·800	0·0070	0·0199	1·100	0·650	0·0280	0·1507	572,450
									597,562
,, 17	4·000	3·700	Nil	0·0806	2·300	0·630	0·0378	0·1759	557,555
									557,724
,, 19	6·000	4·700	0·0112	0·1363	1·300	0·690	0·0280	0·3395	572,450
									572,450
,, 20	6·000	5·300	0·0210	0·1059	1·200	0·683	0·0238	0·3512	545,700
									561,750
,, 21	6·000	5·200	0·0112	0·1063	1·200	0·702	0·0420	0·1967	551,050
									551,050
,, 22	7·000	5·100	Trace	0·6375	1·400	0·712	0·0182	0·1462	545,700
									545,700
,, 23	6·000	5·400	Nil	0·0394	1·300	0·697	0·0140	0·1522	545,700
									567,100
,, 24	3·000	2·900	0·1400	0·3062	1·000	0·545	0·0376	1·1676	524,300
,, 28									588,500
									535,000
,, 29	4·000	3·800	0·0700	0·1362	1·100	0·545	0·0182	0·3093	535,000
									535,000
,, 30	3·000	2·600	0·0560	0·0802	2·000	0·762	0·0322	0·2228	545,700
									535,000
,, 31	6·000	4·100	Nil	0·0231	Lost	0·663	0·0182	0·1143	518,950
1899									
Jan. 2	5·880	4·118	0·1400	Nil	1·473	0·577	0·0210	0·5259	569,764
									561,750
,, 3	6·860	4·706	0·0070	0·0417	1·276	0·663	0·0210	0·5877	549,416
									540,350
,, 4	7·000	4·500	Nil	0·0337	1·400	0·635	0·0420	0·2011	577,505
									551,050
,, 5	7·000	4·600	0·1190	Nil	1·400	0·712	0·1050	0·0675	568,114
									524,300
,, 6	7·000	4·600	0·0240	,,	1·500	0·683	0·0700	Nil	551,050
									540,350
,, 7	6·000	4·200	Nil	0·0344	1·200	0·606	0·0910	0·0959	556,400
									556,400
,, 9	10·000	4·800	0·0140	0·1047	1·300	0·400	0·0840	0·0822	588,500
									561,750
,, 10	6·000	4·300	0·0182	0·0112	1·300	0·680	0·0742	0·1183	540,350
									535,000
,, 11	4·000	2·500	0·1400	Nil	1·300	0·580	0·0350	0·2606	545,700
,, 12	4·000	2·700	0·1050	,,	1·000	0·610	0·0210	0·2190	561,750
									563,415
,, 13	3·000	3·200	0·2800	,,	0·900	0·580	0·0560	0·3084	569,106
									548,923
,, 14	4·000	2·700	0·1050	,,	1·000	0·560	0·0420	0·5275	552,033
									557,724
,, 16	4·000	3·300	0·3500	,,	1·000	0·560	0·0490	0·6667	591,871
									572,450
,, 17	4·000	3·600	0·2100	,,	1·000	0·570	0·0420	0·5380	540,350
									561,750
,, 18	8·000	5·400	0·1050	,,	1·400	0·750	0·0280	0·5451	540,350
,, 19	6·000	4·100	0·1190	,,	1·200	0·654	0·0420	0·3811	521,224
									529,067
,, 20	5·000	4·800	0·0280	,,	1·300	0·635	0·0140	0·2872	537,206
									533,137

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899.									
Jan. 21	5·000	2·600	Nil	Trace	1·100	0·606	0·0420	0·5017	540,350 551,050
„ 23		1·980	0·1610	Nil		0·413	0·0322	0·8640	561,750
„ 24		3·366	0·1330	„		0·452	0·0280	0·5970	561,750
„ 25		3·267	0·0280	„		0·442	Trace	0·5781	561,750
„ 26		3·900	0·0140	0·0654		0·557	0·0140	0·2922	529,650 561,750
„ 27		3·600	0·0210	0·0309		0·546	0·0140	0·1947	535,000 561,750
„ 28		3·100	Nil	0·1456		0·515	0·0140	0·7879	545,700 529,067
„ 30		4·300	„	Trace		0·660	0·0238	0·1524	551,050 545,700
„ 31		5·100	0·0420	0·0767		0·700	0·0210	0·1146	540,350 535,000
Feb. 1		5·400	0·0140	0·0422		0·800	0·0140	0·0854	535,000 508,250
„ 2		5·500	Nil	0·0437		0·840	0·0210	0·1027	563,419 546,342
„ 3		5·000	„	Trace		0·800	0·0210	0·0890	557,554 518,950
„ 4		4·500	„	„		0·740	0·0280	0·1532	535,000 526,300
„ 6		4·300	0·1050	Nil		0·680	0·0140	0·2379	551,050 489,431
„ 7		3·800	0·1260	0·1052		0·630	0·0350	0·1937	529,650 535,000
„ 8		3·300	0·0910	Nil		0·693	0·0210	0·0877	502,900 512,195
„ 9		1·400	0·1750	1·0356		0·500	0·0560	0·5996	518,950
„ 10		2·700	0·1400	0·0931		0·592	0·0308	0·2361	540,650 544,639
„ 11		2·900	Nil	0·0512		0·604	0·0280	0·0510	518,950 527,371
„ 13		3·100	0·0700	Nil		0·653	0·0210	0·3371	507,280 481,500
„ 14		3·800	Nil	0·0162		0·704	0·0210	0·3377	497,235 497,235
„ 15		4·200	0·0140	0·0285		0·690	0·0210	0·3102	511,772 486,850
„ 16		3·900	0·1400	0·1062		0·720	0·0280	0·2682	492,200 497,550
„ 17		4·500	0·0280	0·0914		0·710	0·0280	0·2351	518,950 508,250
„ 18		4·200	Nil	0·0531		0·780	0·0280	0·0930	508,250 502,382
„ 20		4·500	0·0210	0·0652		0·680	0·0210	0·2490	524,300 508,250
„ 21		5·000	Nil	Trace		0·710	0·0140	0·1929	540,350 502,800
„ 22		4·600	0·0140	0·0516		0·770	0·0210	0·0284	535,000 508,250
„ 23		2·400	Trace	0·0900		0·620	0·0210	Nil	492,200
„ 24		4·100	0·0350	0·0331		0·660	0·0280	„	492,200 497,550
„ 25		3·800	Nil	0·1144		0·630	0·0420	0·0080	513,600 518,950
„ 27		3·600	0·0420	0·0692		0·610	0·0280	0·0900	517,326 508,250
„ 28		4·000	0·0140	0·0140		0·622	0·0280	0·2038	502,900 518,950
March 6		4·500	0·0140	0·0604		0·690	0·0350	0·7168	535,000 508,250
„ 7		5·500	0·0070	0·0392		0·810	0·0280	0·2651	492,439 513,600
„ 8		5·300	Nil	0·1944		0·800	0·0140	0·0866	486,850 508,250

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899.									
March 9		5·600	0·0280	0·0370		0·870	0·0140	0·1572	486,850 481,500
,, 10		4·400	0·0280	0·0857		0·720	0·0140	Nil	487,190 492,200
,, 11		3·100	Nil	0·1337		0·660	0·0140	0·1510	483,601
May 8		2·885	Nil	0·1075		0·798	0·3500	10·5910	657,322
,, 9		4·808	0·0070	0·1630		0·879	0·4200	7·9369	633,847
,, 10		5·000	Nil	0·0450		0·919	0·2800	4·2037	642,000
,, 15		2·115	,,	0·1712		0·608	0·0462	4·3138	615,250
,, 16		3·654	,,	Nil		0·500	0·0700	2·4769	615,250
,, 17		2·885	,,	0·1662		0·476	0·0350	2·2525	563,419
,, 18		3·010	,,	0·1162		0·408	0·0308	1·4192	549,415
,, 19		4·423	Trace	Trace		0·592	0·0420	1·4811	563,419
,, 20									563,419
,, 23									584,102
,, 24		2·981	Nil	0·1100		0·524	0·0280	0·9570	563,419
,, 25		2·404	,,	0·1731		0·486	0·0238	0·7087	539,943
,, 26		2·981	,,	0·1206		0·467	0·0280	0·5276	521,224
,, 27		2·788	,,	0·0525		0·505	0·0350	0·4500	539,943
,, 29		3·654	,,	0·1168		0·476	0·0280	0·9957	563,419
,, 30		4·327	,,	0·1194		0·514	0·0462	1·1925	563,419 577,800
,, 31		3·750	,,	Nil		0·604	0·0322	0·6359	539,943 544,639
June 1		3·558	,,	0·0662		0·584	0·0280	0·3826	567,100 539,943
,, 2		3·077	,,	0·1125		0·554	0·0280	0·6338	567,100 549,334
,, 3		2·788	,,	0·0187		0·535	0·0560	0·6752	572,450 516,468
,, 5		3·654	0·0140	0·0747		0·554	0·0210	1·0665	554,029 567,100
,, 6		3·173	Nil	0·0487		0·510	0·0210	0·6646	567,100 551,750
,, 7		1·827	,,	0·0737		0·451	0·0182	0·4049	540,350
,, 8		2·855	,,	0·1043		0·510	0·0210	0·1459	577,800 545,700
,, 9		3·077	,,	0·0675		0·471	Trace	0·2375	472,090 567,100
,, 10		2·404	,,	0·0618		0·500	0·0210	0·3277	549,334 518,950
,, 12		3·173	0·0070	0·1011		0·490	0·0182	0·2780	544,638 529,650
,, 13		3·269	Nil	0·0881		0·500	0·0238	0·5830	539,943 529,650
,, 14		4·528	,,	0·0681		0·667	0·0210	0·3015	539,943 540,350
,, 15		4·423	,,	0·0700		0·725	0·0420	0·2517	549,333 540,350
,, 16		4·134	,,	0·0262		0·725	0·0350	0·1975	530,553 508,250
,, 17									511,772 518,950
,, 19		4·423	,,	0·0900		0·676	0·0210	0·7509	516,468 508,250
,, 20		4·038	0·0042	0·0795		0·689	0·0350	0·6212	532,393 508,250
,, 21		4·528	Nil	0·1400		0·621	0·0210	0·2127	530,553 497,550
,, 22		2·788	,,	0·0744		0·621	0·0210	0·1165	502,382 497,550
,, 23		1·000	,,	0·1394		0·466	0·0238	0·2393	527,371
,, 24		3·173	,,	0·0987		0·641	0·0350	0·1075	508,250 527,371
,, 26		2·885	,,	0·1944		0·600	0·0238	0·4149	508,250 527,371
,, 27		3·269	,,	0·0862		0·610	0·0280	0·3445	492,200 512,303

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed. Oxygen absorbed from permanganate in four hours. By the total oxidisable matter.	Sewage: Oxygen absorbed from permanganate in four hours. By the dissolved oxidisable matter.	Sewage: Nitrogen as Nitrite.	Sewage: Nitrogen as Nitrate.	Coke-bed effluent. Oxygen absorbed from permanganate in four hours. By the total oxidisable matter.	Coke-bed effluent: Oxygen absorbed from permanganate in four hours. By the dissolved oxidisable matter.	Coke-bed effluent: Nitrogen as Nitrite.	Coke-bed effluent: Nitrogen as Nitrate.	Quantity treated. Gallons.
1899. June 28		3·558	Nil.	0·1075		0·630	0·0280	0·5101	481,500 502,900
„ 29		3·269	Trace	0·0381		0·640	0·0322	0·4447	508,250 551,050
„ 30		2·788	Nil	0·1606		0·590	0·0280	0·3376	497,550 502,900
July 1		2·019	„	0·1337		0·530	0·0378	0·5684	481,500 508,250
„ 3		3·365	„	0·0994		0·520	0·0238	0·6343	535,000 518,950
„ 4		3·846	„	0·0537		0·529	0·0280	0·5170	508,250 508,250
„ 5		3·558	„	0·0862		0·559	0·0280	0·3901	486,850 508,250
„ 6		1·635	„	0·1137		0·451	Trace	0·2843	486,850
„ 7		2·308	„	0·0562		0·539	0·0378	0·1865	527,371 507,077
„ 8		1·827	„	0·1034		0·471	0·0308	0·1804	497,550 486,850
„ 10		2·212	„	0·0650		0·500	0·0280	0·5657	527,371 447,672
„ 11		2·971	„	0·0331		0·622	0·0238	0·1331	497,550 486,850
„ 12		3·269	„	0·1037		0·674	0·0350	0·2437	527,371 481,500
„ 13		2·971	„	0·1012		0·643	0·0350	0·2100	507,281 481,500
„ 14		2·788	„	0·1387		0·582	Nil	0·2331	497,550 451,742
„ 15		2·596	„	0·0337		0·674	0·0448	0·2064	496,409 508,250
„ 17		3·048	„	0·2200		0·581	0·0252	0·5668	492,992 481,500
„ 18		2·962	„	0·0787		0·612	0·0280	0·5890	492,992 492,200
„ 19		2·962	„	Trace		0·581	0·0350	1·8051	488.297 513,600
„ 20		2·761	„	„		0·561	0·0280	0·0980	497,550 497,550
„ 21		2·381	„	„		0·551	0·0210	0·0984	486,850 502,900
„ 22		1·619	„	0·0772		0·490	0·0238	0·1116	492,200
„ 24		2·380	„	0·1758		0·514	0·0210	0·4592	535,000 518,950
„ 25		3·238	„	0·2491		0·476	0·0210	0·2823	508,250 486,850
„ 26		3·052	„	0·1807		0·609	0·0210	0·1620	481,500 481,500
„ 27		3·052	„	0·1882		0·580	0·0252	0·4280	502,900 447,010
„ 28		2·631	„	0·1206		0·628	0·0252	0·3384	455,811 446,040
„ 29		Lost	„	0·2930		0·636	0·0210	0·3370	502,258 422,564
„ 31		3·093	„	0·1791		0·555	0·0210	0·2208	492,213 446,040
Aug. 1		3·505	„	0·1796		0·572	0·0182	0·3408	399,605 377,229
„ 2		2·268	„	0·2346		0·570	0·0210	0·3321	416 979 508,250
„ 3		3·402	„	0·2392		0·580	0·0210	0·3951	481,500 470,800
„ 4		3·505	„	0·1297		0·580	0·0128	0·2883	481,500 454,750
„ 5									481,500
„ 8		1·702	„	0·1785		0·534	0·0210	0·2456	444,050 470,800

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899.									
Aug. 9		2·062	Nil.	0·1477		0·485	0·0140	0·2827	465,450 465,450
„ 10		2·371	„	0·2415		0·485	0·0210	0·9540	470,800 454,750
„ 11		2·500	„	0·3016		0·566	0·0182	0·4639	465,450 454,750
„ 12		2·500	„	0·2378		0·639	0·0252	0·3377	470,800 455,285
„ 14		2·700	„	0·2366		0·601	0·0210	0·2310	422,564 454,750
„ 15		2·900	„	0·3696		0·592	0·0210	0·5131	422,564 454,750
„ 16		2·900	„	0·0705		0·563	0·0210	0·4603	422,564 492,200
„ 17		2·500	„	0·1186		0·533	0·0182	0·2235	422,564 454,750
„ 18		2·400	„	0·1201		0·524	0·0182	0·2836	417,869 460,100
„ 19		1·700	„	0·3603		0·512	0·0238	0·5799	427,259
„ 21		2·083	„	0·1790		0·500	0·0210	0·3167	508.250 422,564
„ 22		2·500	„	0·2986		0·521	0·0210	0·5723	470,800 454,750
„ 23		2·916	„	0·1068		0·521	0·0210	0·3418	454,750 460,100
„ 24		2·395	„	0·3582		0·574	0·0140	0·5841	481,500 460,100
„ 25		2·812	„	0·3058		0·680	0·0128	0·5847	406,975 460,100
„ 26		2·500	„	0·4112		0·667	0·0252	0·7454	406,975 427,260
„ 28		3·226	„	0·2351		0·594	0·0140	0·3503	481,500 454,750
„ 29		3·215	„	0·3611		0·625	0·0210	0·5769	454,750 454,750
„ 30		2·796	„	0·0850		0·583	0·0140	0·2876	454,750 454,750
„ 31		2·688	„	0·2398		0·427	0·0210	0·4607	481,500 454,750
Sept. 1		4·285	„	0·0620		0·670	0·0140	0·2258	422,564 454,750
„ 2		2·526	„	0·2406		0·680	0·0210	0·4615	454,750
„ 4		2·211	„	0·4737		0·503	0·0140	0·6966	481,500 454,750
„ 5		2·812	„	0·3551		0·505	0·0140	0·5791	470,800 422,564
„ 6		1·915	„	0·2996		0·670	0·0112	0·4643	422,564 454,750
„ 7		2·340	„	0·4765		0·558	0·0182	0·5824	465,450 454,750
„ 8		2·447	„	0·3558		0·579	0·0182	0·5718	460,100 454,750
„ 9		3·469	„	0·2928		0·706	0·0210	0·5900	460,100 422,564
„ 11		2·842	„	0·1081		0·645	0·0182	0·2243	481,500 454,750
„ 12		2·316	„	0·2008		0·624	0·0182	0·4099	431,955 460,100
„ 13		3·263	„	0·0401		0·763	0·0210	0·0972	422,564 431,955
„ 14		2·128	„	0·2436		0·581	0·0182	0·3453	427,260 465,450
„ 15		2·978	„	0·2378		0·354	0·0182	0·3411	408,479 454,750
„ 16		2·446	„	0·2980		0·623	0·0210	0·6960	417,869 419,184
„ 18		2·872	„	0·0720		0·494	0·0140	0·4628	431,955 465,450

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated. Gallons.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	
1899.									
Sept. 19		2·021	Nil.	0·2410		0·494	0·0140	0·3470	422,564
„ 20		3·191	„	0·2916		0·634	0·0210	0·7043	455,285
									460,100
„ 21		3·404	„	0·2384		0·553	0·0280	0·7890	454,750
									454,750
„ 22		3·085	„	0·1315		0·559	0·0210	0·6045	454,750
									454,750
„ 23		3·085	„	0·3029		0·602	0·0182	1·0698	454,750
									470,800
„ 25		3·298	„	0·3586		0·505	0·0140	0·5726	481,500
									454,750
„ 26		3·723	„	0·2391		0·559	0·0182	0·4045	454,750
									460,100
„ 27		4·042	„	0·1930		0·602	0·0140	0·5900	454,750
									454,750
„ 28		3·229	„	0·1986		0·495	0·0140	0·4030	454,750
									460,100
„ 29		2·708	„	0·3460		0·580	0·0280	0·5715	481,500
									460,976
„ 30		2·187	„	0·3758		0·428	0·0210	0·5845	454,750
									454,750
Oct. 2		3·645	„	0·3645		0·523	0·0182	0·6042	455,285
									455,285
„ 3		2·000	„	0·2385		0·452	0·0140	0·3491	454,750
									460,100
„ 4		2·812	„	0·6206		0·428	0·0182	1·4370	454,750
„ 5		2·105	„	0·4320		0·750	0·0140	0·6018	454,750
									454,750
„ 6		2·812	„	0·4922		0·490	0·0140	0·8105	449,400
									454,750
„ 7		2·947	„	0·4800		0·600	0·0182	0·8236	454,750
									454,750
„ 9		2·812	„	0·1325		0·620	0·0140	0·4785	470,800
									406,974
„ 10		2·947	„	0·2912		0·700	0·0218	0·5882	454,750
									454,750
„ 11		3·654	„	0·3578		0·600	0·0218	0·5732	454,750
									455,285
„ 12		3·654	„	0·3936		0·660	0·0210	0·7047	449,400
									454,750
„ 13		4·038	„	0·3624		0·690	0·0210	0·5830	454,750
									454,750
„ 14		3·654	„	0·2224		0·660	0·0280	0·4586	422,564
									454,750
„ 16		3·461	„	0·1780		0·480	0·0210	0·4505	431,955
									454,750
„ 17		3·557	„	0·2417		0·605	0·0210	0·3975	454,750
									454,750
„ 18	3·365	2·211	„	0·3035	0·543	0·456	0·0140	0·4767	460,100
„ 19	4·059	2·673	„	0·3728	0·620	0·500	0·0140	0·4765	454,750
									454,750
„ 20	3·663	2·475	„	0·3993	0·590	0·480	0·0182	0·5980	454,750
									454,750
„ 21	3·861	2·574	„	0·2486	0·610	0·450	0·0182	0·4047	454,750
									441,987
„ 23	4·507	3·431	„	0·1844	0·666	0·558	0·0140	0·3526	486,850
									465,450
„ 24	5·098	3·833	„	0·2359	0·764	0·607	0·0140	0·4683	460,100
									465,450
„ 25	5·000	3·725	„	0·1802	0·794	0·607	0·0210	0·3416	460,100
									454,750
„ 26	4·803	3·431	„	0·0977	0·754	0·598	0·0182	0·2171	460,100
									454,750
„ 27	4·215	3·431	„	0·0871	0·784	0·637	0·0182	0·2843	454,750
									454,750
„ 28	3·333	2·058	„	0·0300	0·663	0·500	0·0182	0·0607	438,212
									454,750
„ 30	3·725	2·549	„	0·0505	0·672	0·427	0·0140	0·0787	443,903
									454,750

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed.				Coke-bed effluent.				Quantity treated.
	Oxygen absorbed from permanganate in four hours.		Nitrogen as		Oxygen absorbed from permanganate in four hours.		Nitrogen as		
	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrite.	Nitrate.	Gallons.
1899.									
Oct. 31	5·294	3·725	Nil.	0·0592	0·618	0·518	0·0140	0·1381	449,400 454,750
Nov. 1	4·607	3·333	,,	0·1846	0·690	0·545	0·0140	0·4785	454,750 454,750
,, 2	3·823	2·450	,,	0·0565	0·520	0·429	0·0280	0·0905	454,750 454,750
,, 3	2·941	1·862	0·1120	0·0388	0·591	0·469	0·0182	0·3509	460,100
,, 4	1·960	1·078	0·0840	0·3460	0·540	0·387	0·0350	0·4618	472,358 455,285
,, 6	2·058	1·274	0·1120	0·2560	0·415	0·336	0·0280	0·3945	455,285 438,212
,, 7	3·333	2·549	0·5600	0·0525	0·574	0·455	0·0350	0·3340	455,285 454,750
,, 8	4·117	2·254	0·0420	0·3013	0·504	0·396	0·0210	0·5996	454,750 460,100
,, 9	3·137	2·254	0·0560	0·0867	0·554	0·445	0·0140	0·2923	454,750 454,750
,, 10	4·126	2·647	0·0700	0·2201	0·416	0·307	0·0210	0·3040	422,564 422,564
,, 11	2·647	1·764	Nil	Trace	0·526	0·419	0·0210	0·2133	422,564 422,564
,, 13	4·216	3·333	,,	0·0603	0·616	0·482	0·0210	0·3324	422,564 454,750
,, 14	4·901	3·823	,,	0·1224	0·660	0·526	0·0280	0·2717	422,564 422,564
,, 15	4·500	3·500	,,	0·1806	0·634	0·461	0·0210	0·3491	347,482 422,564
,, 16	4·400	4·000	,,	0·0973	0·596	0·480	0·0280	0·3370	422,564 454,750
,, 17	1·700	1·300	,,	0·0354	0·443	0·413	0·0210	0·3541	460,100
,, 18	4·400	2·600	,,	0·0675	0·634	0·480	0·0420	0·4360	422,564 347,482
,, 20	4·200	3·200	,,	0·0596	0·586	0·471	0·0420	0·4560	465,450 454,750
,, 21	4·803	3·725	,,	0·1810	0·622	0·513	0·0420	0·5680	422,564 347,482
,, 22	5·196	4·117	,,	0·1146	0·651	0·522	0·0420	0·4154	422,564 454,750
,, 23	4·313	3·529	0·0560	0·2420	0·963	0·899	0·0700	0·6475	347,482 366,277
,, 24	4·705	3·529	Nil	0·3067	0·558	0·477	0·0560	0·4388	354,432 347,482
,, 25	4·356	3·465	,,	0·0581	0·563	0·447	0·0420	0·1917	429,259 452,750
,, 27	5·248	4·455	,,	0·0800	0·660	0·602	0·0140	0·5360	454,750 347,482
,, 28	5·800	4·500	0·0280	0·0333	0·702	0·615	0·0322	0·1540	465,450 449,400
,, 29	5·700	4·200	0·0140	0·0985	0·760	0·635	0·0322	0·0928	454,750 454,750
,, 30	5·500	4·300	0·0140	0·0170	0·712	0·635	0·0322	0·0102	465,450 470,800
Dec. 1	5·700	4·500	0·0322	0·0481	0·731	0·630	0·0210	0·1480	465,450 460,976
,, 2	3·300	2·200	Nil	0·3006	0·811	0·555	0·0210	0·4638	455,285
,, 4	3·900	2·600	0·0420	0·2041	Lost	0·666	0·0280	0·2766	454,750 426,830
,, 5	3·400	2·900	0·0280	0·3445	0·759	0·601	0·0210	0·5923	454,750 426,830
,, 6	4·200	3·700	Nil	0·0606	0·685	0·527	0·0210	0·2802	455,285 432,521
,, 7	5·445	4·059	,,	0·0598	0·734	0·632	0·0210	0·2218	454,750 438,212
,, 8	5·148	4·059	0·0560	0·0635	0·663	0·561	0·0280	0·1010	465,450 386,626
,, 9	4·800	3·300	Nil	0·1231	0·650	0·620	0·0420	0·3251	454,750 454,750
,, 11	5·600	4·700	,,	0·2481	0·740	0·670	0·0420	0·5714	454,750 454,750

TABLE 7—(*continued*).

Date, 1898.	Sewage chemically treated and sedimented as supplied to the coke-bed. Oxygen absorbed from permanganate in four hours. By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrogen as Nitrite.	Nitrate.	Coke-bed effluent. Oxygen absorbed from permanganate in four hours. By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrogen as Nitrite.	Nitrate.	Quantity treated. Gallons.
1899.									
Dec. 12	6·000	5·400	Nil	0·1172	0·740	0·700	0·0420	0·5473	454,750
„ 13	6·300	5·600	„	Trace	0·720	0·680	0·0350	0·2110	444,050 422,564
„ 14	5·200	4·900	„	0·2975	0·708	0·669	0·0420	0·3710	449,400 454,750
„ 15	4·900	4·300	0·0560	0·1300	0·660	0·583	0·0420	0·2547	438,700 422,564
„ 16	3·400	1·900	Nil	0·2493	0·349	0·349	0·0420	0·3236	438,700 454,750
„ 18	4·000	3·600	0·0560	0·0616	0·543	0·436	0·0420	0·2519	454,750
„ 19	4·300	3·400	0·0560	0·1808	0·485	0·405	0·0420	0·4155	454,750 438,700
„ 20	5·000	4·200	0·0560	0·0041	0·663	0·485	0·0350	0·3874	454,750 440,050
„ 21	5·200	4·000	0·0560	0·0546	0·574	0·465	0·0420	0·2688	454,750 454,750
„ 22	6·100	5·500	0·0420	0·1978	0·841	0·742	0·0280	0·3335	454,750 440,050
„ 27	6·100	4·900	0·0490	0·0710	0·723	0·523	0·0700	0·5400	406,974
„ 28	5·800	4·900	0·0560	0·0558	0·628	0·485	0·0210	0·5332	454,750 454,750
„ 29	5·300	4·300	0.0420	0·0691	0·828	0·666	0·0140	0·4425	454,750 454,750
„ 30	4·300	2·900	Nil	0·1167	0·543	0·467	0·0280	0·3802	444,050 454,750

AVERAGES.

Date.	Oxygen absorbed from permanganate in 4 hours. By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrogen as Nitrite.	Nitrate.	Oxygen absorbed from permanganate in 4 hours. By the total oxidisable matter.	By the dissolved oxidisable matter.	Nitrogen as Nitrite.	Nitrate.	Remarks.
1898 May 12—May 23		3·039				0·623			One filling.
May 25—July 2		2·655	Nil	0·0059		0·509	0·0252	0·1145	
July 4—July 29		2·877	Nil	0·0061		0·624	0·0221	0·0615	Two fillings.
Nov. 8—Nov. 19	5·045	3·525	Nil	0·1114	1·018	0·567	0·0474	0·6738	One filling.
1899 Nov. 21—Jan. 21	5·465	4·108	0·0610	0·0594	1·183	0·613	0·0321	0·3979	Two fillings.
1899 Jan. 23—Mar. 11		3·987	0·0396	0·0783		0·665	0·0233	0·2407	
May 8—Oct. 17		2·976	0·0003	0·1814		0·574	0·0308	0·7118	Two fillings after first three weeks.
Oct. 18—Dec. 30	4·443	3·393	0·0291	0·1411	0·642	0·529	0·0290	0·3483	
1898 May 12—July 2		2·726	Nil	0·0059		0·530	0·0252	0·1145	One filling.
1899 Nov. 21—Mar. 11	5·465	4·057	0·0518	0·0683	1·183	0·635	0·0283	0·3300	Two fillings.
1899 May 8—Dec. 30	4·443	3·109	0·0095	0·1686	0·643	0·560	0·0302	0·5963	
1898 1899 May 12—Dec. 30	4·921	3·306	0·0186	0·1158	0·900	0·580	0·0294	0·4531	Whole period.
PERCENTAGE PURIFICATION.									
1898 May 12—July 2						80·5			
1899 Nov. 21—Mar. 11					78·4	84·3			
1899 May 8—Dec. 30					85·5	82·0			

2.—CROSSNESS RESULTS.

TABLE 8.—DETAILS OF THE ANALYTICAL RESULTS OBTAINED FROM THE CRUDE SEWAGE AND THE EFFLUENT FROM THE BACTERIAL BEDS.

Date.	Crude sewage.				Coke-bed effluent.		
	Number of fillings per day.	Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as		Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Nitrogen as	
			Nitrite.	Nitrate.		Nitrite.	Nitrate.
1899.							
Feb. 27	One	3·039	Nil	Nil	1·614	0·014	Trace
28	,,	4·300	,,	,,	2·500	Trace	,,
Mar. 1	,,	2·600	,,	,,	1·500	Nil	Nil
2	,,	3·418	,,	,,	1·827	0·007	0·030
3	,,	4·620	,,	,,	2·815	Trace	Nil
4	,,	2·942	,,	,,	1·629	Nil	,,
6	,,	3·511	,,	,,	2·021	0·014	Trace
7	,,	2·766	0·021	,,	1·915	0·070	,,
8	,,	2·872	Trace	,,	0·958	0·084	0·052
10	,,	3·191	Nil	,,	1·489	Nil	0·095
11	,,	3·085	,,	Trace	1·489	0·021	0·040
13	,,	3·737	0·014	Nil	1·212	0·021	0·110
14	,,	2·525	Nil	Trace	0·999	Trace	0·037
15	,,	2·632	,,	Nil	0·947	Nil	Trace
16	,,	3·263	,,	,,	1·158	,,	0·077
17	,,	2·947	,,	,,	1·158	0·021	Trace
18	,,	3·158	,,	,,	1·370	0·035	0·136
20	,,	2·604	,,	,,	1·042	0·070	Trace
21	,,	4·271	,,	,,	1·562	0·014	0·143
22	,,	6·459	Trace	,,	3·125	0·021	0·083
23	,,	3·263	0·007	,,	1·369	0·014	0·071
24	,,	4·062	Nil	,,	1·770	0·007	0·128
25	,,	2·917	,,	,,	1·042	0·021	0·114
27	Two	3·036	Trace	,,	1·518	Nil	0·142
28	,,	3·482	Nil	,,	1·875	0·021	Nil
29	,,	2·679	,,	,,	1·429	0·007	0·109
April 4	,,	3·100	,,	,,	1·400	0·042	Trace
5	,,	2·000	,,	,,	1·200	0·014	0·123
6	,,	3·200	Trace	,,	1·800	Nil	0·038
7	,,	2·800	0·028	0·011	1·400	0·007	0·080
8	One	2·700	Nil	Nil	1·500	0·014	0·078
10	Two	3·725	0·014	,,	1·961	0·007	0·056
11	,,	3·039	Nil	,,	1·470	0·014	0·213
12	,,	4·314	Trace	,,	2·568	0·070	0·044
13	,,	2·451	0·007	Trace	1·372	Nil	0·081
14	,,	3·921	Nil	Nil	2·451	0·014	0·060
15	One	3·137	0·021	,,	1·862	0·014	0·138
17	,,	4·301	Nil	,,	2·680	0·028	0·136
18	Two	3·824	0·007	Trace	2·680	0·014	0·054
19	,,	2·574	Trace	Nil	1·453	0·042	0·285
20	,,	5·247	Nil	,,	3·014	Nil	Trace
21	,,	4·444	,,	,,	2·525	0·014	0·184
22	One	4·646	0·021	,,	3·030	0·007	0·253
24	Two	3·878	0·028	Trace	2·245	0·014	0·210
25	,,	2·653	Trace	Nil	1·617	Trace	Trace
26	,,	2·842	Nil	,,	1·789	Nil	0·322
27	,,	2·857	,,	Trace	1·667	0·021	0·148
28	,,	4·742	0·007	0·034	2·755	0·056	0·180
29	One	3·542	0·007	Nil	2·371	0·042	Trace
May 1	Two	2·846	0·014	,,	1·579	Trace	0·170
2	,,	2·340	Nil	,,	1·474	0·070	0·094
3	,,	3·298	,,	,,	1·959	0·021	0·208
4	,,	4·480	,,	,,	2·660	Nil	0·045
5	One	3·830	Trace	,,	2·340	0·007	0·241
6	,,	3·300	0·007	Trace	1·800	0·014	Trace
8	Two	4·216	Nil	,,	2·451	Nil	0·180
9	,,	3·301	,,	Nil	1·863	Trace	0·094
10	,,	2·277	,,	,,	1·078	0·056	0·231
11	,,	2·784	,,	,,	1·443	0·070	Trace
12	One	3·299	,,	,,	1·735	0·014	Nil
13	,,	2·143	,,	,,	1·237	0·028	0·113
15	Two	3·535	,,	,,	1·919	0·028	Nil
16	,,	4·124	,,	,,	2·755	Trace	,,
17	,,	2·300	,,	,,	1·400	0·007	0·204
18	,,	3·800	0·035	,,	2·000	0·098	0·046
19	,,	1·700	Nil	,,	0·800	0·021	0·133
24	,,	4·255	,,	,,	2·553	0·042	0·320
25	,,	3·298	,,	,,	1·702	0·070	0·055
26	,,	2·826	,,	,,	1·277	0·070	0·121
27	One	2·766	,,	,,	1·596	0·084	0·219
29	Two	2·632	0·014	,,	1·579	0·035	0·147

TABLE 8.—(*continued*).

Date.	Crude sewage. Number of fillings per day.	Crude sewage. Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Crude sewage. Nitrogen as Nitrite.	Crude sewage. Nitrogen as Nitrate.	Coke-bed effluent. Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Coke-bed effluent. Nitrogen as Nitrite.	Coke-bed effluent. Nitrogen as Nitrate.
1899.							
May 30	Two	3·298	Nil	Nil	2·021	0·007	0·253
31	,,	3·958	,,	,,	2·283	0·070	0·273
June 1	,,	3·263	,,	,,	1·789	0·028	Nil
2	,,	2·900	,,	,,	1·400	0·028	0·128
3	One	2·800	,,	,,	1·500	0·014	Trace
5	Two	2·727	,,	,,	1·313	0·070	,,
6	,,	3·400	0·028	,,	1·900	0·140	Nil
7	,,	3·900	Nil	,,	2·500	0·098	0·045
8	One	2·772	,,	,,	1·881	0·014	0·157
9	,,	3·267	0·028	,,	1·683	0·021	0·108
19	Two	3·737	0·014	,,	2·020	0·084	0·320
20	,,	2·653	Nil	,,	1·530	0·070	0·038
21	,,	4·388	,,	,,	2·653	0·014	0·207
22	,,	3·500	0·007	Trace	1·900	0·028	0·114
23	,,	3·367	Nil	Nil	2·041	Nil	0·083
24	One	2·449	,,	,,	1·326	0·042	0·039
26	Two	3·438	0·014	,,	1·875	Nil	Trace
27	,,	2·813	Nil	,,	1·458	,,	Nil
28	,,	2·604	0·007	,,	1·458	0·028	0·204
29	,,	1·649	Nil	,,	0·825	0·007	Trace
30	,,	4·845	,,	,,	2·165	Nil	0·183
July 1	One	2·165	Trace	,,	1·134	0·035	0·256
3	Two	1·920	Nil	,,	1·010	0·007	Trace
4	,,	1·735	,,	,,	0·512	Trace	0·080
5	,,	2·020	,,	,,	1·111	0·014	Nil
6	,,	2·755	,,	,,	1·224	0·021	0·317
7	One	1·837	,,	,,	1·021	Trace	0·148
10	Two	2·376	,,	,,	1·386	Nil	Trace
11	,,	3·000	Trace	,,	1·700	,,	0·055
14	,,	2·323	Nil	,,	1·414	0·070	0·146
15	One	2·930	Trace	,,	1·515	Trace	0·106
17	Two	4·615	,,	Trace	2·308	,,	0·333
18	,,	3·516	Nil	Nil	1·319	Nil	0·134
19	,,	2·967	,,	,,	1·648	,,	Nil
20	,,	3·696	Trace	,,	2·174	Trace	0·083
21	One	2·777	Nil	,,	1·555	,,	0·068
25	Two	3·152	,,	,,	1·739	Nil	0·873
31	One	2·222	,,	,,	0·889	0·070	0·492
Aug. 1	Two	2·889	,,	,,	1·222	Nil	Nil
2	,,	4·667	,,	,,	2·667	,,	0·485
3	,,	2·857	,,	,,	1·758	0·044	Nil
4	,,	3·763	,,	,,	2·473	Trace	0·364
9	,,	3·778	,,	,,	2·111	0·028	Nil
10	,,	3·736	,,	,,	2·088	Trace	0·358
11	,,	3·736	,,	,,	2·527	Nil	Nil
12	One	3·804	,,	,,	2·069	,,	Trace
14	,,	2·527	,,	,,	2·087	,,	0·2647
15	Two	3·951	,,	,,	2·790	,,	Nil
16	,,	3·493	,,	,,	1·929	,,	0·5045
21	One	4·942	,,	,,	2·414	,,	Nil
22	Two	4·369	,,	,,	2·896	,,	,,
23	,,	4·045	,,	,,	1·574	,,	,,
24	,,	4·943	,,	,,	2·248	,,	0·6271
25	,,	4·118	,,	,,	1·882	0·056	0·1740
26	One	3·529	,,	,,	1·412	Trace	1·1025
28	Two	5·048	,,	,,	2·041	0·0056	Nil
29	,,	5·102	,,	,,	2·245	Trace	Trace
30	,,	3·265	,,	,,	2·347	Nil	0·5294
31	,,	3·939	,,	,,	1·919	0·035	Nil
Sept. 1	,,	3·571	,,	,,	1·735	Nil	,,
2	One	3·300	,,	,,	1·190	,,	0·1765
4	Two	2·525	,,	,,	1·313	,,	Nil
5	,,	3·300	,,	,,	1·100	,,	,,
6	,,	3·030	,,	,,	1·717	0·014	,,
7	,,	3·366	,,	,,	1·735	0·028	0·3770
9	One	2·857	,,	,,	2·449	Nil	Nil
11	Two	2·857	,,	,,	1·633	,,	,,
12	,,	4·040	,,	,,	1·616	0·3860	,,
13	,,	4·286	,,	,,	2·245	Nil	,,
14	,,	4·592	,,	,,	1·837	,,	,,
15	,,	1·020	,,	,,	0·918	,,	,,
16	One	2·200	,,	,,	1·700	0·2647	0·0112
18	Two	3·700	,,	,,	1·400	Nil	Nil

Table 8.—(*continued*).

Date.	Crude sewage. Number of fillings per day.	Crude sewage. Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Crude sewage. Nitrogen as Nitrite.	Crude sewage. Nitrogen as Nitrate.	Coke-bed effluent. Oxygen absorbed from permanganate in four hours by the dissolved putrescible matter.	Coke-bed effluent. Nitrogen as Nitrite.	Coke-bed effluent. Nitrogen as Nitrate.
1899.							
Sept. 19	Two	4·216	Nil	Nil	1·667	Trace	0·0098
20	,,	4·257	,,	,,	1·881	0·2164	Nil
21	,,	4·300	,,	,,	1·600	Nil	Trace
22	,,	3·900	,,	,,	1·700	,,	Nil
23	One	3·431	,,	,,	1·667	0·0916	,,
25	Two	2·871	,,	,,	1·485	Nil	,,
26	,,	4·608	,,	,,	1·667	Trace	0·0280
27	,,	2·857	,,	,,	1·099	Nil	Trace
28	,,	4·725	,,	,,	1·868	,,	Nil
29	,,	2·826	,,	,,	1·304	Trace	,,
Oct. 2	,,	2·747	0·0168	,,	1·648	0·0350	,,
3	,,	4·505	Nil	,,	1·319	0·0280	Trace
4	,,	5·000	,,	,,	2·127	0·0210	0·3494
5	,,	4·176	,,	0·1752	1·649	Nil	Trace
6	,,	4·222	,,	Nil	1·555	,,	Nil
7	One	3·279	,,	,,	0·659	,,	,,
9	Two	4·945	,,	,,	1·760	,,	,,
13	One	4·456	,,	,,	1·521	,,	,,
16	,,	2·151	,,	,,	1·182	0·0378	0·2361
23	,,	4·545	,,	,,	1·515	0·3930	Trace

Date. 1899.	Number of fillings per day.	Crude Sewage. Oxygen absorbed from permanganate in 4 hours. By the total putrescible matter.	Crude Sewage. Oxygen absorbed from permanganate in 4 hours. By the dissolved putrescible matter.	Crude Sewage. Nitrogen as Nitrite.	Crude Sewage. Nitrogen as Nitrate.	Coke-Bed Effluent. Oxygen absorbed from permanganate in 4 hours. By the total putrescible matter.	Coke-Bed Effluent. Oxygen absorbed from permanganate in 4 hours. By the dissolved putrescible matter.	Coke-Bed Effluent. Nitrogen as Nitrite.	Coke-Bed Effluent. Nitrogen as Nitrate.
Nov. 7	Two	6·000	2·946	0·0952	Trace	2·321	1·473	0·3780	1·2117
8	,,	6·000	4·210	Nil	,,	2·936	2·326	0·2100	1·0980
9	,,	6·000	3·053	0·0168	0·0573	2·210	1·358	0·1470	0·4011
10	,,	6·355	2·917	0·0070	Nil	2·601	1·500	0·0798	Nil
11	One	6·314	2·946	Nil	,,	2·321	1·358	0·1470	0·7270
14	Two	6·288	3·814	,,	,,	1·855	1·855	Nil	Nil
15	,,	7·031	3·609	,,	,,	2·371	1·855	,,	,,
16	,,	6·041	3·442	,,	,,	2·500	2·396	,,	,,
17	,,	5·051	3·300	,,	,,	2·062	1·670	,,	,,
18	One	4·737	3·263	,,	,,	2·316	2·026	,,	0·1763
20	Two	5·625	4·026	,,	,,	1·562	1·458	0·0393	Trace
21	,,	6·459	6·159	,,	,,	2·917	2·078	Nil	0·0886
22	,,	6·296	4·722	,,	,,	2·315	2·129	,,	Trace
23	,,	9·074	5·642	,,	0·0796	2·129	2·037	,,	0·1436
24	,,	7·685	4·629	,,	Nil	2·407	1·825	,,	Nil
25	One	4·537	2·685	,,	,,	1·388	1·203	,,	,,
27	Two	9·174	6·055	,,	,,	3·119	2·752	,,	0·0591
28	,,	8·718	5·779	,,	,,	3·846	3·211	,,	0·0835
29	,,	7·830	4·710	,,	,,	2·547	1·792	,,	0·1743
30	,,	7·339	4·312	,,	,,	2·568	1·926	,,	Trace
Dec. 1	,,	6·605	3·669	,,	,,	2·568	1·926	,,	,,
2	One	6·880	5·229	,,	,,	1·834	1·642	,,	Nil
4	Two	9·174	6·330	,,	,,	2·110	1·468	,,	,,
5	,,	7·957	4·731	,,	,,	2·105	1·720	,,	,,
6	,,	8·125	5·834	,,	,,	2·917	1·979	,,	,,
7	,,	7·579	5·473	,,	,,	3·579	2·631	,,	,,
8	,,	7·683	4·734	,,	,,	2·726	2·000	,,	,,
9	One	3·871	2·903	,,	,,	2·473	1·496	,,	,,
12	,,	7·938	5·361	,,	Trace	2·165	1·236	0·028	0·3481
13	Two	7·526	5·051	,,	Nil	2·887	2·062	Nil	Trace
14	,,	6·354	4·583	,,	,,	2·500	1·536	,,	Nil
15	One	6·956	5·217	,,	,,	2·826	2·282	,,	,,
16	,,	6·210	5·369	,,	,,	2·105	1·894	,,	,,
18	Two	4·376	3·541	,,	,,	2·601	1·771	,,	,,
19	One	9·592	6·938	0·007	Trace	5·102	2·347	0·091	0·2383
20	,,	9·278	6·701	Nil	Nil	4·020	3·299	Nil	Nil
21	,,	5·307	3·775	,,	Trace	2·347	1·836	,,	0·1179
22	,,	14·949	8·383	,,	Nil	4·545	3·434	,,	Trace
Averages.									
Feb. 27—March 25			3·399	0·0019	0·0000		1·587	0·0189	0·0486
March 27—Oct. 23			3·386	0·0023	0·0016		1·774	0·0274	0·1163
Nov. 7—Dec. 22		7·077	4·633	0·0034	0·0037	2·624	1·968	0·0295	0·1282
March 27—Dec. 22		7·077	3·650	0·0026	0·0020	2·624	1·815	0·0279	0·1188
Feb. 27—Dec. 22		7·077	3·622	0·0025	0·0018	2·624	1·789	0·0269	0·1108

TABLE 9.—DETAILS OF THE ANALYTICAL RESULTS OBTAINED FROM THE TREATMENT OF CRUDE SEWAGE BY RAPID SEDIMENTATION FOLLOWED BY INTERMITTENT TREATMENT IN A COKE-BED.

Date.	Daily average rate of flow of the sewage through the channels. Feet per minute.	Average daily samples of the sewage subjected to sedimentation, collected during 24 hours' flow.				Average samples of the portion of sedimented sewage subjected to coke-bed treatment.	
		Oxygen absorbed from permanganate in four hours.					
		By the total oxidisable matter in the sewage.	By the dissolved oxidisable matter in the sewage.	By the total oxidisable matter in sewage effluent after sedimentation.	By the dissolved oxidisable matter in the sewage effluent after sedimentation.	By the dissolved oxidisable matter in the sewage effluent after sedimentation and before coke-bed treatment.	By the dissolved oxidisable matter in the effluent from the coke-bed.
1899.							
Dec. 24	10·6	6·735	4·082	5·204	3·877	...	...
25	9·0	6·392	4·227	5·051	4·020	4·316	2·830
26	9·4	6·916	4·299	6·074	4·392	3·720	2·081
27	8·3	7·245	5·102	6·530	5·204	3·855	2·081
28	11·5	8·061	5·714	6·735	5·612	4·400	2·000
29	12·8	8·989	5·555	7·171	5·454	3·600	1·700
30	5·8	7·938	3·093	6·146	3·750	3·500	1·660
31	5·2	7·187	4·270	5·876	3·195	...	...
1900.							
Jan. 1	9·9	7·083	4·061	5·416	4·166	2·963	1·394
2	7·1	6·562	3·646	5·833	3·750	3·708	1·650
3	6·3	7·745	4·705	6·372	4·705	5·106	2·172
4	4·3	6·019	3·883	4·174	3·689	4·480	2·059
5	4·8	6·956	5·326	6·521	5·000	4·736	2·020
6	5·1	6·333	3·888	5·333	4·000	3·826	1·913
7	5·9	6·333	3·444	5·444	3·777	...	...
8	6·9	6·593	4·615	6·252	4·615	3·700	1·500
9	7·3	7·234	4·489	6·489	4·042	2·800	1·300
10	6·5	7·174	5·109	6·087	5·217	3·333	1·616
11	6·3	6 739	4·782	6·087	5·000	3·737	1·212
12	5·6	7·766	5·000	6·490	5·319	4·217	1·992
13	5·8	6·989	4·516	5·698	4·622	4·602	2·043
	7·4	7·095	4·467	5·952	4·448	3·922	1·846
Average percentage purification	...	...	...	16·1	0·4	12·2	58·7 on the crude sewage. 52·9 on the sedimented sewage.

DIVISION II.—BACTERIOLOGICAL.

BY

A. C. HOUSTON, M.B., D.Sc.

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DIVISION II.—BACTERIOLOGICAL.

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VIII.—Engravings of Micro-photographs and Diagrammatic Drawings.

DIVISION II.–BACTERIOLOGICAL.

I.–SUMMARY OF THE CONTENTS OF PREVIOUS REPORTS.

1.—SUMMARY OF THE CONTENTS OF THE FIRST REPORT.*

In this Report a description of some of the methods used in the bacteriological examination of sewage was given, and the results of the bacteriological examination of nine samples of Barking and six samples of Crossness crude sewage as regards the total number of bacteria, the number of spores of bacteria and the number of liquefying bacteria, and as regards the species of micro-organisms present were expressed in the form of a table.

Fourteen micro-photographs illustrating the work accompanied the Report.

The chief results obtained may be stated as follows—

1 Description of the sample of crude sewage.	2 Total number of bacteria in 1 c.c.	3 Number of spores of bacteria in 1 c.c.	4 Number of liquefying bacteria in 1 c.c.	5 Number of *B. coli* (or closely allied forms) in 1 c.c.	6 No. of spores of *B. enteritidis sporogenes* (Klein) in 1 c.c.
Barking— Crude sewage (9 samples)	3,899,259	332 (excluding extreme results).	430,750	Usually more than 100,000	From 10 to 1,000 (usually more than 100).
Crossness— Crude sewage (6 samples)	3,526,667	365 (excluding extreme results).	400,000	Usually more than 100,000	From 10 to 1,000 (usually more than 100).

Although prior to the publication of this Report there were numerous records of the total number of micro-organisms in raw sewage, it is believed that there were few, if any, data dealing with the systematic examination of samples of crude sewage as regards the estimation of the number of aërobic bacteria present in the form of spores, the number of microbes causing liquefaction of gelatine, the number of *B. coli* and spores of the pathogenic *B. enteritidis sporogenes*.

Such records were considered to be highly important as preparatory to a study of the effluents from biological coke-beds. Moreover these records have a special interest from the point of view of the bacterioscopic examination of drinking water.‡ Thus pure water rarely contains more than 100-200 bacteria per c.c. and very few, if any, spores in a similar quantity. As regards liquefying bacteria, these are present in considerable numbers even in very pure waters, but they are for the most part different in sort from those found in sewage.§ *B. coli* is not present, or only in small numbers in water free from any objectionable pollution, and the spores of *B. enteritidis sporogenes* are absent from as much, it may be, as 100 to 500 c.c. of a pure water.

It is worthy of note that relatively to the total number of microbes, the number of spores of bacteria is much greater in surface soils† than in sewage or in water. Further, that pure soils do not contain the spores of *B. enteritidis sporogenes* even in as much as 10 mgrms. of the soil, whereas impure soils may contain 10,000 per gramme. Lastly, *B. coli* appears to be absent from pure virgin soils and present, it may be, in considerable numbers in soils *recently* polluted.

Although the estimation of the total number of micro-organisms, the number of spores of bacteria, and the number of liquefying germs was considered not unimportant, chief stress is to be laid on the enumeration of *B. coli* and spores of *B. enteritidis sporogenes*.

B. coli is an organism characteristic of the intestinal discharge of animals, and especially abundant therein. Moreover, it may be pathogenic, although it can hardly be considered as a pathogenic microbe under ordinary conditions and in the usual acceptation of the term. Certainly, however, its presence serves as an index of the possible presence of other and perhaps dangerous bacteria of recent animal outcome.

* The Report contained a record of the work done from February 23rd to May 9th, 1898. Filtration of sewage. Report on the bacteriological examination of London crude sewage. First Report. (P. S. King and Son, 2 and 4, Great Smith-street, Westminster, S.W.)

‡ It is remarkable that notwithstanding the fact that sewage is the most common and most dangerous source of the pollution of drinking waters so little is known of the bacterial composition of sewage.

§ For example: in the Second Report a large number of experiments are given showing that in sewage and in the effluents from bacterial beds a gas-forming rapidly liquefying microbe described as "*sewage proteus*" is present in numbers usually exceeding 100,000 per c.c. This micro-organism was sometimes found to be very virulent.

† Report of the Medical Officer, Local Government Board, 1897–8.

As regards *B. enteritidis sporogenes*, this anaërobe is not only typical of excremental matters, but its cultures are extremely virulent to animals, and Dr. Klein's researches point to its being causally related to certain cases of acute diarrhœa in the human subject.

There was a manifest advantage in choosing two micro-organisms—one an aërobe and the other an anaërobe, with the object of counting their numbers first in the crude sewage and afterwards in the effluent from bacterial coke-beds and *B. coli* and *B. enteritidis sporogenes* seemed to be microbes peculiarly well-fitted for the purpose.

2.—SUMMARY OF THE CONTENTS OF THE SECOND REPORT.*

The Report is divided into a chemical and bacteriological division.

DIVISION I.—CHEMICAL.

Here Dr. Clowes deals with the chemical and practical side of the question under (1) objects of the coke-bed experiments; (2) general results obtained; (3) general conclusions; (4) advantages of bacterial over chemical treatment; (5) construction and details of the coke-beds; (6) methods of working the beds and their condition at the time of writing the Report; (7) history of each coke-bed; (8) experimental proof of the aëration of the coke-beds; (9) variation in the condition of the raw sewage, and its effect upon the effluent; (10) comparative purity of clear sewage, bacterial effluent and chemical effluent.

DIVISION II.—BACTERIOLOGICAL.

It is this division of the Report which it is now proposed to summarise.

It will be remembered that the First Report dealt with a period extending from the end of February to the beginning of May, 1898, and with the bacteriological examination of the raw sewage only—the bacterial coke-beds being at the period referred to in course of construction. The Second Report carried the enquiry a stage further, since it dealt with the bacteriological examination of the effluents from the bacterial coke-beds as well as of the raw sewage. The main portion of the Report treated of a period extending from May 9th to August 9th, 1898. But in the Addenda A, B, C, D, E, further bacteriological records were given, bringing the work up to the end of that year. The following summary takes note of the whole of the above period. As the descriptive matter in the Second Report dealt only with the period from May 9th to August 9th, 1898, and as the records contained in the Addenda A, B, C, D, E covered a large interval of time (August 9th to December 31st, 1898) it will be necessary to collect all the figures together and to summarise the results as a whole.

It is of advantage first to give the chief results† obtained in the form of tables and then to make certain comments thereon.

But before doing so, it is desirable to state in a few sentences what the contents of the Second Report were. It will, of course, be impossible to summarise all the different sections, and for information under the headings not dealt with in the following pages reference must be made to the Report itself.

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A.—Introduction.

B.—Summary of Contents of First Report

I.—The Biological Treatment of Sewage.

II.—General Results obtained (May 9th to August 9th, 1898).

III.—Summary of Results shewn in Table 1.—1. Total number of Bacteria. 2. Number of Spores of Bacteria. 3. Number of Liquefying Bacteria. 4. Species of Micro-organisms. (*a*) B. Enteritidis Sporogenes (Klein). (*b*) B. Coli Communis. (*c*) Other species of Bacteria.

IV.—Tables and Diagrams dealing with the Results of the Bacteriological Examination of the Crude Sewage, of the Effluents from the Coke-beds; and of the Effluent from the Chemical Precipitation Works, and of Samples of Thames Water.

V.—Description of some of the Bacteria found in the Crude Sewage, and in the Effluents from the Coke-beds. 1. B. Coli Communis. 2. B. Mesentericus. (*a*) B. Mesentericus E. (*b*) B. Mesentericus I. 3. Sewage Proteus. 4. B. Frondosus. 5. B. Fusiformis. 6. B. Subtilissimus. 7. B. Subtilis. Sewage variety A. Sewage variety B. 8. B. Membraneus Patulus. 9. B. Capillareus.

VI.—Description of Micro-photographs and Diagrammatic Drawings accompanying the Report.

VII.—Addenda A, B, C, D, E.—Further Bacteriological Records (August 9th to December 31st, 1898.)

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* Bacterial treatment of crude sewage (Second Report.) Experimental intermittent treatment of London crude sewage in the coke-beds at Crossness. (P. S. King and Son, 2 and 4, Great Smith-street, Westminster, S.W.)

† The figures are not *strictly* comparable with those given in the First Report, because in order to obtain corresponding samples of the raw sewage and of the effluents from the coke-beds, a somewhat longer interval elapsed between the time of the collection of the samples of crude sewage and their subsequent examination than was the case during the earlier portion of the enquiry.

In the following pages the chief results as regards (1) total number of bacteria, (2) number of spores of bacteria, (3) number of liquefying bacteria, (4) number of *B. coli*, and (5) number of spores of *B. enteritidis sporogenes* are tabulated and summarised. Both the records contained in the text of the Second Report and those given in the Addenda A, B, C, D, E, are here dealt with.

The necessity of collecting these figures together, and making brief comments thereon, will make the summary less concise than it would otherwise have been.

(*a*) Total Number of Bacteria in 1 c.c.

	Date.	Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
	1898.				
Second Report, page 21	May 11	3,930,000	4,800,000	...	...
	18	3,670,000	4,100,000	...	...
	25	6.400,000	6,100,000	...	...
	June 9	6,500,000	1,200,000	...	...
	15	4,000,000	5,300,000	...	...
	22	9,100,000	3,000,000	...	...
	July 20	12,800,000	9,200,000	...	...
	27	7,200,000	...	6,600,000	...
	August 4	4,200.000	1,800,000	...	...
	9	3,600,000	...	1,700,000	...
Second Report, Addendum A.	19	5,800,000	3,400,000	...	...
	24	4,100,000	...	5,700,000	...
	September 14	8,000,000	3,400,000	...	...
	21	8,600,000	...	7,200,000	...
	28	7,500,000	7,500,000	...	...
	October 5	10,500,000	...	8,000,000	...
	12	4,000,000	4,200,000	...	...
	21	8,000,000	...	15,800,000	...
	26	5,200,000	...	...	3,100,000
	November 9	7,800,000	8,800,000	...	...
	16	5,800,000	...	5,300,000	...
	23	8,600,000	...	...	4,500,000
	30	13,500,000	5,400,000	...	...
	December 7	5,600,000	...	4,000,000	...
	14	19,500,000	...	...	5,300,000
	21	7,400,000	6,300,000	...	...
	Averages ...	7,357,692 (26 samples)	4,966,666 (15 samples)	6,787,500 (8 samples)	4,300.000 (3 samples)
	Percentage reduction (as compared with the raw sewage).		32 per cent.	7 per cent.	41 per cent.
Average number of bacteria in the raw sewage when the samples were comparative with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds.		6,973,333 (15 samples corresponding to 4 ft. samples.	4,966,666 28 per cent. reduction.		
		6,675,000 (8 samples corresponding to 6 ft. primary samples.)	... ...	6,787,500 slight increase.	
		11,100,000 (3 samples corresponding to 6 ft. secondary samples.)	... ...	... ...	4,300,000 61 per cent. reduction.

The table shows that the total number of bacteria in the crude sewage (26 samples), the effluent from the 4-foot coke-bed (15 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (3 samples) averaged 7,357,692, 4,966,666, 6,787,500, and 4,300,000 per c.c. respectively. The percentage reduction of bacteria in the effluents being 32, 7, and 41. The average number of bacteria in the 15 samples of crude sewage corresponding to the 4-foot coke-bed effluents was 6,973,333. In the eight samples corresponding to the 6-foot primary coke-bed effluents the average was 6,675,000. Lastly, the three samples of crude sewage corresponding to the 6-foot secondary coke-bed effluents yielded on an average 11,100,000 bacteria per c.c. Calculated from these figures, the percentage reduction of bacteria was 28 as regards the 4-foot coke-bed effluents; no reduction, but a slight increase as regards the 6-foot primary coke-bed effluents, and 61 per cent. in respect of the 6-foot secondary coke-bed effluents.

As a rule a rise or fall above or below the mean in the number of bacteria in the crude sewage was associated with a similar increase or decrease of microbes in the corresponding effluents. Thus, as regards the crude sewage and 4-foot coke-bed effluents, there was a correspondence in this respect on 11 occasions out of 15; and as regards the raw sewage and 6-foot primary coke-bed effluents this correspondence was observed in all the eight samples. The records

of the examination of the 6-foot secondary coke-bed effluents are too few in number to allow of useful conclusions being drawn, but here also the same agreement occurred. The above must not be taken as meaning that the percentage deviation from the mean showed any parallelism as regards the crude sewage and corresponding effluents.

So far as a diminution in the number of bacteria may be taken as an indication of purification, it must be admitted that the above results are not satisfactory. And if they are unfavourable from the point of view of percentage reduction effected, still less are they favourable when judged by the actual state of the effluents.

It is noteworthy that the reduction in the number of bacteria was much greater in the effluent from the 4-foot coke-bed than in the effluent from the 6-foot primary coke-bed, and was nearly as much as in the effluent from the 6-foot secondary coke-bed.

Possibly the records as regards the 6-foot primary coke-bed indicate a retrogade change.

Since the coke-beds are intended to encourage the life processes of bacteria it might be urged that an increase, or, at all events, the absence of a marked decrease in the number of bacteria in the effluents is of little importance. Further, that it may even be a desirable thing that an effluent only partially purified should carry with it the bacteria which have been engaged in the work of purification in order to complete their work. There may be truth in these contentions, but as experience has shown that the bacterial beds which yield the best chemical results yield also the best results bacteriologically, and as river water already contains all the necessary germs of putrefaction and nitrification, it would seem to be undesirable to discharge with an effluent countless germs of a kind to be associated with the recent evacuations of animals. Moreover, some of these micro-organisms are pathogenic, and doubtless many of them, although perhaps slowly working in the direction of purification, are, in a sense, intruders. since the work could probably be more efficiently carried out in their absence by other and unobjectionable bacteria.

As regards the value to be assigned to the estimation of the total number of microbes, it may be said that the greater the number of micro-organisms in a liquid containing a mixed bacterial flora the more likely is it that some of them are of a harmful nature. But further than this, the prolonged investigations carried out in this enquiry as regards the species of microbes and their relative numbers give to the above figures a special and peculiar value. For while there is no fixed proportion between the total number of bacteria, and, for example, the number of proteus-like germs, of *B. coli* and of spores of *B. enteritidis sporogenes*, it has been abundantly shown that *with a sample of effluent or raw sewage, containing an average number of microbes, say three to nine millions per c.c., the number of "sewage proteus" of B. coli and of spores of B. enteritidis sporogenes is likely to be not less than* 100,000 *; at least* 100,000, *and usually more than* 100 *respectively. Further, that more than one-tenth of the bacteria are likely to be "liquefiers," and only about one in* 20,000 *present as spores* (*aërobes*).

As the bacterial composition of London crude sewage does not differ widely from the raw sewage of most other towns, it is believed that these records have a wide range of usefulness. At the risk of repetition it may be pointed out that their bearing on the bacterioscopic examination of potable waters is very important.

(*b*) Number of Spores of Aërobic Bacteria in 1 c.c.

Second Report, page 22. Second Report, Addendum C.]

Date.		Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke - bed.
1898					
May	11	460	260	...	...
	18	300	140	...	...
	25	370	380	...	...
June	9	560	230	...	...
	15	180	300	...	...
	22	310	60	...	...
July	20	400	430	...	...
	27	870	...	480	...
August	4	280	220	...	...
	9	340	...	300	...
	19	220	200	...	...
	24	170	...	180	...
September	14	*	*	...	...
	21	250	...	190	...
	28	260	490	...	...
October	5	200	...	130	...
	12	320	240	...	...
	21	340	...	420	...
	26	200	...	...	220
November	9	150	140	...	...
	16	240	...	180	...
	23	510	...	...	320
	30	440	310	...	...
December	7	70	...	170	...
	14	800	...	...	420
	21	270	140	...	...
Averages	...	340 (25 samples.)	252 (14 samples).	256 (8 samples).	320 (3 samples).
Percentage reduction (as compared with the raw sewage).			25 per cent.	24 per cent.	5 per cent.

* The rapid liquefaction of the gelatine prevented accurate counting.

(*b*) Number of Spores of Aerobic Bacteria in 1 c.c.—*continued.*

Date.	Crossness crude sewage.	Effluent from 4-ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
Average number of spores of bacteria in the raw sewage where the samples were comparative with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds. ...	322 (14 samples, corresponding to 4ft. samples).	252 21 per cent. reduction.		
	310 (8 samples corresponding to 6 ft. primary samples)	...	256 17 per cent. reduction.	
	503 (3 samples corresponding to 6 ft. secondary samples).	...	...	320 36 per cent. reduction.

The table shows that the number of spores of bacteria in the crude sewage (25 samples), the effluent from the 4-foot coke-bed (14 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (3 samples), averaged 340, 252, 256, and 320 per c.c. respectively. The percentage reduction in the effluents as compared with the crude sewage being 25, 24, and 5. The average number of spores in the 14 samples of crude sewage corresponding to the 4-foot coke-bed effluents was 322; in the 8 samples corresponding to the 6-foot primary coke-bed effluents, 310; and in the 3 samples corresponding to the 6-foot secondary coke-bed effluent the average was 503. Calculated from these figures the percentage reduction in the number of spores of bacteria was 21 as regards the 4-foot coke-bed effluents, 17 as regards the 6-foot primary coke-bed effluents, and 36 in respect of the 6-foot secondary coke-bed effluents.

Usually a rise or fall above or below the mean in the number of spores of bacteria in the raw sewage was associated with a similar increase or decrease in the number in the corresponding effluents. Thus as regards the crude sewage and 4-foot coke-bed effluents there was in this respect a relation between the two in 11 out of 14 samples; and the raw sewage and 6-foot primary coke-bed effluents showed a similar correspondence in six out of eight comparative samples. The same relationship was noticed with reference to the 6-foot secondary coke-bed effluents, but here only three samples were examined.

So far as may be judged from a rise or fall above or below the mean the figures show no distinct parallelism between the total number of bacteria and the number of spores of bacteria in the case either of the crude sewage or of the effluents from the 6-foot primary coke-bed. But as regards the 4-foot coke-bed effluents there is evidence of a distinct relation.

It will be understood that in the above remarks, when mention is made of a relationship, it does not imply a parallelism as regards *percentage* deviation from the mean.

In the Second Report it was shewn that the percentage reduction in the number of bacteria and the number of spores of bacteria in the 4-foot coke-bed effluent as compared with the crude sewage was 27·7 and 38 respectively. Here and when dealing with a larger number of records, i.e., including those given in Addenda A and C, as well as those contained in the body of the Report, the figures are slightly different, being in the first case 32 per cent. and in the second 25 per cent.

It is difficult to gauge the exact significance of the number of spores of aërobic bacteria and the number relative to the total number of bacteria. Spores of bacteria are peculiarly resistant to unfavourable physical conditions; fortunately, however, the majority, at all events, of the spores of *aërobic* micro-organisms found in sewage belong to species which are believed to be harmless.

Although the actual number of spores in sewage is large, the number relative to the total number of bacteria is very small. Thus in the 26 samples above recorded for every microbe present in the spore-form there were present over 21,000 in the vegetative-form. And this result is not in all probability to be traced solely to the comparative infrequency of bacteria in sewage *capable* of forming spores, but also to the active and continued multiplication of the micro-organisms in the presence of an abundance of suitable pabulum. In the case of effluents from bacterial beds it is conceivable that a smaller reduction in the number of spores of bacteria as compared with the reduction in the total number of bacteria, or an actual increase in the number of spores in the effluent as compared with the crude sewage might be a good rather than a bad sign as indicating that the organic pabulum was becoming exhausted and the conditions for bacterial life so unfavourable as to lead the microbes to form spores so as to escape extinction.

In my reports to the Local Government Board on the bacteriological examination of soils I have shewn that in surface soils not only is the number of spores very large, but also that they are very numerous in relation to the total number of bacteria. Thus in soils it is common to find the ratio between the number of spores and number of bacteria—1 : 2 ; 1 : 3 ; 1 : 4 ; 1 : 5 ; 1 : 6 ; 1 : 7 ; 1 : 8 ; 1 : 9 and 1 : 10. Sometimes the ratio may be 1 : 20 ; 1 : 30 ; 1 : 40, or lower, but here the

cause is usually to be found in the presence of an excess of moisture and also of organic pabulum. Although the number of bacteria capable of forming spores in soils is peculiarly great, it is probable that the majority of these form spores only when there is a deficiency in the amount of liquid organic pabulum and when the physical conditions are unfavourable.

It is, perhaps, permissible to hazard the conjecture that an increase (actual or relative) in the number of spores of bacteria in effluents from bacterial beds is possibly a favourable sign. Yet surmises such as the above are best received with caution, especially as they are to some extent founded on a comparison between a liquid (sewage) in the one case and a solid (soil) in the other.

Certainly, however, it is a point worth noting that in soils the ratio of spores to bacteria is commonly more than 1 : 10 and in sewage less than 1 : 10,000. Waters, it may be added, differ rather widely in this respect, but they always approximate much more closely to the ratio found in sewage than to that found in soil.

(c) Number of Bacteria causing Liquefaction of Gelatine in 1 c.c.

	Date.	Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft secondary coke-bed.
	1898.				
Second Report, page 23	May 11	400,000	1,300,000	...	...
	18	100,000	700,000	...	...
	25	900,000	700,000	...	...
	June 9	1,400,000	200,000	...	...
	15	800,000	1,100,000	...	...
	22	900,000	600,000	...	...
	July 20	1,700,000	1,000,000	...	...
	27	900,000	...	300,000	...
	August 4	400,000	500,000	...	...
	9	1,100,000	...	200,000	...
Second Report, Addendum B.	19	600,000	400,000	...	...
	24	600,000	...	1,100,000	...
	September 14	700,000	700,000	...	...
	21	1,200,000	...	1,100,000	...
	28	1,200,000	1,200,000	...	...
	October 5	2,400,000	...	600,000	...
	12	700,000	1,200,000	...	...
	21	1,000,000	...	1,000,000	...
	26	700,000	...	...	500,000
	November 9	1,900,000	1,400,000	...	...
	16	1,600,000	...	1,500,000	...
	23	900,000	...	...	400,000
	30	900,000	500,000	...	...
	December 7	1,400,000	...	900,000	...
	14	1,400,000	...	...	1,600,000
	21	2,200,000	600,000	...	...
	Averages... ...	1,076,923 (26 samples)	806,666 (15 samples)	837,500 (8 samples)	833,333 (3 samples)
	Percentage reduction (as compared with the raw sewage)		25 per cent.	22 per cent.	22 per cent.
Average number of liquefying bacteria in the raw sewage where the samples were comparative with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds.		986,666 (15 samples corresponding to 4 ft. samples)	806,666 18 per cent. reduction		
		1,275,000 (8 samples corresponding to 6 ft. primary samples)	... ...	837,500 34 per cent. reduction	
		1,000,000 (3 samples corresponding to 6 ft. secondary samples)	... ...	... ...	833,333 16 per cent. reduction

The table shows that the number of liquefying bacteria in the crude sewage (26 samples), the effluent from the 4-foot coke-bed (15 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (3 samples) averaged 1,076,923, 806,666, 837,500, and 833,333 per c.c. respectively. The percentage reduction in the number of liquefying bacteria in the effluents being respectively 25, 22, and 22. The average number of liquefying bacteria in the 15 samples of crude sewage corresponding to the 4-foot coke-bed effluents was 986,666. In the 8 samples corresponding to the 6-foot primary coke-bed effluents

the average was 1,275,000, and in the 3 samples corresponding to the 6-foot secondary coke-bed effluents 1,000,000. Calculated from these figures the percentage reduction of liquefying bacteria was 18 as regards the 4-foot coke-bed effluents, 34 in respect of the 6-foot primary coke-bed effluents, and 16 as regards the 6-foot secondary coke-bed effluents.

Usually a rise or fall above or below the mean in the number of liquefying bacteria in the crude sewage was associated with a similar increase or decrease in the number in the corresponding effluents. Thus as regards the crude sewage and 4-foot coke-bed effluents, in 10 out of the 15 experiments there was a correspondence, and in the case of the 6-foot primary coke-bed effluents, 4 out of the 8 samples corresponding to the crude sewage showed a similar relationship. Only 3 samples of the effluent from the 6-foot secondary coke-bed were examined; these in each case were related to the raw sewage in the above sense.

So far as may be judged from a rise or fall above or below the mean, the figures show a certain parallelism between the total number of bacteria in the crude sewage and the number of liquefying bacteria, and lastly between the number of spores and liquefiers.

As regards the 4-foot coke-bed effluents there is evidence of a distinct relation between the total number of bacteria and spores of bacteria, the total number of bacteria and the number of liquefying bacteria, but little or none between the number of spores and number of liquefiers.

With respect to the 6-foot primary coke-bed effluents there is no definite correspondence between the total number of bacteria and either the number of spores of bacteria or the number of liquefiers; and the spores and liquefiers show, if anything, an inverse relation.

It is to be noted that the number of liquefying bacteria was less in the effluents from the 4-foot coke-bed than in the effluents either from the 6-foot primary or 6-foot secondary coke-beds.

The exact value to be placed on the determination of the number of liquefying bacteria is difficult to judge of. At one time it was thought that the greater the number of liquefying bacteria in a water the more dangerous was the nature of the contamination, and the more unfit the water was for domestic use. But as many objectionable bacteria (e.g., *B. coli*) do not liquefy gelatine and many pure waters are rich in liquefying microbes of a harmless nature, this test fell into comparative disfavour. When, however, the character of the liquefying bacteria in the substance under examination is taken into consideration, the position of things is somewhat altered. Thus in 14 samples of crude sewage and effluents there were present at least 100,000 gas-forming "*sewage proteus*"* per c.c. So that it may safely be said that at least one-tenth of the numerous liquefying bacteria in sewage are proteus-like in character. And as some of the *strains* of this "*sewage proteus*" isolated from the raw sewage and the effluents were found to be very virulent, it may be added that crude sewage and effluents from bacterial coke-beds are not only rich in liquefying bacteria, but that they contain liquefying germs in great abundance which are very objectionable in kind.

In conclusion it is worthy of note that the ratios of spores and of liquefiers to the total number of bacteria in the crude sewage and effluents are as follows—

Crude sewage (26 samples)—Ratio of spores (aërobes) to total number of bacteria	= 1 : 21,640
4-foot coke-bed effluent (15 samples)—Ratio of spores (aërobes) to total number of bacteria	= 1 : 19,709
6-foot primary coke-bed effluent (8 samples)—Ratio of spores (aërobes) to total number of bacteria ...	= 1 : 26,513
6-foot secondary coke-bed effluent (3 samples)—Ratio of spores (aërobes) to total number of bacteria ...	= 1 : 13,436
Crude sewage (26 samples)—Ratio of liquefiers to total number of bacteria	= 1 : 6·8
4-foot coke-bed effluent (15 samples)—Ratio of liquefiers to total number of bacteria	= 1 : 6·1
6-foot primary coke-bed effluent (8 samples)—Ratio of liquefiers to total number of bacteria	= 1 : 8·1
6-foot secondary coke-bed effluent (3 samples)—Ratio of liquefiers to total number of bacteria	= 1 : 5·1

These results would seem to indicate that the result of the bacterial treatment of the raw sewage in the coke-beds was to effect an increase in the number of spores and of liquefiers relative to the total number of micro-organisms in the case of the 4-foot and 6-foot secondary beds and to bring about a decrease in the number of spores and liquefiers relative to the total number in the case of the 6-foot primary coke-bed. In the Second Report it was stated that the percentage reduction of spores was greater than the reduction of the total number of micro-organisms in the 4-foot coke-bed effluent as compared with the crude sewage. The figures, however, dealt only with the period extending from May 9th to August 9th, whereas the above records include as well hose given in Addenda to the Second Report—i.e., the results obtained between August 9th to December 31st, 1898.

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* This micro-organism is fully described in Section V., Division II., of Second Report.

(*d*) Number of B. Coli or Closely Allied Forms in 1 c.c.

	Date.	Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. (primary) coke-bed.	Effluent from 6 ft. (secondary) coke-bed.
	1898.				
Second Report, page 26	May 11	None in 0·00001 c.c.	200,000	...	...
	18	300,000	200,000	...	...
	25	1,500,000	700,000	...	...
	June 9	200,000	100,000	...	...
	15	300,000	600,000	...	...
	22	300,000	300,000	...	...
	July 20	300,000	300,000	...	...
	27	500,000	...	600,000	...
	August 4	200,000	300,000	...	...
	9	1,000,000	...	200,000	...
Second Report, Addendum D.	19	100,000	None in 0·00001 c.c.	...	...
	24	300,000	...	400,000	...
	September 14	600,000	400,000	...	...
	21	1,600,000	...	700,000	...
	28	1,000,000	900,000	...	...
	October 5	1,200,000	...	1,300,000	...
	12	800,000	500,000	...	...
	21	800,000	...	800,000	...
	26	None in 0·00001 c.c.	...	...	None in 0·00001 c.c.
	November 9	400,000	400,000	...	...
	16	300,000	...	500,000	...
	23	600,000	...	...	100,000
	30	600,000	200,000	...	...
	December 7	400,000	...	200,000	...
	14	400,000	...	...	100,000
	21	500,000	600,000	...	...
	Averages... ... (in round numbers)	600,000 (24 samples)	400,000 (14 samples)	600,000 (8 samples)	100,000 (2 samples)
	Percentage reduction (as compared with the raw sewage).		33 per cent.	No reduction.	83 per cent.
Average number of B. coli in the raw sewage where the sample corresponded with the samples obtained respectively from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-bed.		538,000 (13 samples corresponding to 4 ft. samples.)	400,000 25 per cent. reduction.		
		762,000 (8 samples corresponding to 6 ft. primary samples.)	... ...	600,000 21 per cent. reduction.	
		500,000 (2 samples corresponding to 6 ft. secondary samples.)	... ...	... ...	100,000 80 per cent. reduction.

The table shows that the number of *B. coli* in the crude sewage (24 samples), the effluent from the 4-foot coke-bed (14 samples), the effluent from the 6-foot primary coke-bed (8 samples), and the effluent from the 6-foot secondary coke-bed (2 samples) averaged 600,000, 400,000, 600,000 and 100,000 per c.c. respectively. The percentage reduction in the effluents as compared with the crude sewage being 33, no reduction, and 83. The average number of *B. coli* in the 13 samples of crude sewage corresponding to the 4-foot coke-bed effluent was 538,000; in the 8 samples corresponding to the 6-foot primary coke-bed effluents 762,000; and in the 2 samples corresponding to the 6-foot secondary coke-bed effluents the average was 500,000. Based on these figures the percentage reduction in the number of *B. coli* was 25 as regards the 4-foot coke-bed effluents, 21 as regards the 6-foot primary coke-bed effluents, and 80 in respect of the 6-foot secondary coke-bed effluents.

Usually a rise or fall above or below the mean in the number of *B. coli* in the crude sewage was associated with a similar increase or decrease in the number in the corresponding effluents. Thus as regards the crude sewage and 4-foot coke-bed effluents there was in this respect a correspondence between the two in 10 out of 12 samples; and the raw sewage and 6-foot primary coke-bed effluents showed a similar relation in 6 out of the 7 comparative samples. The records as regards the 6-foot secondary coke-bed effluents are too few in number to warrant a comparison being made.

So far as may be judged from a rise or fall above or below the mean the figures show a certain parallelism between the number of *B. coli* and the total number of bacteria both in the crude sewage and in the effluents from the 4-foot and 6-foot primary coke-beds. The records as regards the 6-foot secondary coke-bed are too few to allow of useful conclusions being drawn.

It is to be noted that the average number of *B. coli* in the 6-foot primary coke-bed effluent

was greater than the number in the 4-foot coke-bed effluent, and, indeed, showed no difference from the raw sewage in this respect.

The ratio of the number of *B. coli* to the total number of bacteria in the crude sewage and in the effluents is approximately as follows—

Crude sewage (26 samples)—Ratio of *B. coli* to total number of bacteria = 1 : 12
4-foot coke-bed effluent (15 samples)—Ratio of *B. coli* to total number of bacteria ... ... = 1 : 12
6-foot primary coke-bed effluent (8 samples)—Ratio of *B. coli* to total number of bacteria ... ... = 1 : 11
6-foot secondary coke-bed effluent (3 samples)—Ratio of *B. coli* to total number of bacteria ... ... = 1 : 43

These results would seem to indicate that the result of the bacterial treatment of the raw sewage in the coke-beds was to effect no material alteration in the number of *B. coli* relative to the total number of bacteria in the case of the 4-foot and 6-foot primary coke-beds and to bring about a decrease in the case of the 6-foot secondary coke-bed. In the latter case, however, only 3 samples were examined.

(*e*) Number of Spores of B. Enteritidis Sporogenes in 1 c.c.

	Date.	Crossness crude sewage.	Effluent from 4-ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. coke-bed again passed through the laboratory vessel at Crossness.	Effluent from 6 ft. secondary coke-bed.
	1898.					
Second Report, pages 24 and 25.	May 11	at least 10 but less than 100	at least 100 but less than 1,000			
	18	at least 1,000 ...	at least 100 but less than 1,000			
	25	at least 100 but less than 1,000	at least 1,000			
	June 9	at least 100 ...	at least 100			
	15	at least 10 ...	at least 10			
	22	at least 1,000 ...	at least 10 but less than 100			
	July 6	at least 10 but less than 100	...	at least 10 but less than 100		
	20	at least 100 but less than 1,000	at least 100 but less than 1,000	at least 100 ...	at least 100	
	27	at least 100 ...	at least 100 but less than 1,000	at least 100 ...	at least 10 but less than 100	
	Aug. 4	at least 100 ...	at least 100 ...	at least 10 ...	at least 10	
	9	at least 10 but less than 100	at least 100 ...	at least 100 ...	at least 10 but less than 100	
Second Report, Addendum E.	19	at least 100 ...	at least 100 ...	at least 10 ...	at least 10	
	24	at least 100 but less than 1,000	at least 100 ...	at least 100 but less than 1,000	at least 10 but less than 100	
	Sept. 14	at least 1,000 ...	at least 100 but less than 1,000	at least 10 but less than 100	effluent from 6 ft. primary coke-bed now turned on to 6 ft. secondary coke-bed	at least 100
	21	at least 1,000 ...	at least 100 ...	at least 100 but less than 1,000	”	at least 100
	28	at least 100 but less than 1,000	at least 100 but less than 1,000	at least 100 ...	”	at least 100
	Oct. 5	at least 100 but less than 1,000	at least 100 ...	at least 100 but less than 1,000	”	at least 100
	12	at least 1,000 ...	at least 1,000 ...	at least 100 ...	”	at least 10 but less than 100
	21	at least 100 but less than 1,000	at least 100 ...	at least 100 but less than 1,000	”	at least 100
	26	at least 100 but less than 1,000	less than 10 ...	at least 100 ...	”	at least 1,000
	Nov. 2	at least 10 ...	at least 10 ...	at least 10 ...	”	at least 10
	9	at least 1,000 ...	at least 1,000 ...	at least 100 ...	”	at least 100
	16	at least 1,000 ...	at least 100 ...	at least 100 but less than 1,000	”	at least 10 but less than 100
	23	at least 1,000 ...	at least 100 ...	at least 100 ...	”	at least 100 but less than 1,000
	30	at least 1,000 ...	at least 100 but less than 1,000	at least 100 ...	”	at least 100
	Dec. 7	at least 10 but less than 100	at least 100 ...	at least 100 but less than 1,000	”	at least 10 but less than 100
	14	at least 100 but less than 1,000	at least 10 and ? 100	at least 10 and ? 100	”	at least 100 but less than 1,000
	21	at least 1,000 ...	at least 1,000 ...	? 10, less than 100	”	? 10, less than 100

In summarising these results it is to be noted that—

(1) The number of spores of *B. enteritidis sporogenes* in the crude sewage and effluents varied as a rule from 10 to 1,000 per c.c. Usually there were more than 100.

(2) The bacterial treatment did not produce any significant alteration in the number of spores of this pathogenic anaërobe, and sometimes the number was greater in the effluents than in the corresponding samples of crude sewage. Possibly this may be due to the spores being stored in the coke-beds and being occasionally washed out. This supposition may also explain the observed fact that sometimes the number of spores of aërobic bacteria in the effluents was greater than in the corresponding sample of sewage. Speaking generally, and dealing only with the experiments where the samples of raw sewage and effluent corresponded, and where the absence of *B. enteritidis* was established in an amount of liquid one-tenth less than the quantity in which it was found to be present, it may be said that the number of spores of enteritidis was more often observed to be less in the effluents as compared with the corresponding sample of crude sewage than *vice versa*.

In view of these results, and remembering the virulence of this microbe and its probable relation to certain cases of acute diarrhœa in the human subject, it is remarkable that some bacteriologists still assert that the effluents from bacterial beds are free from pathogenic germs.

Another point on which some misconception is evident is the belief that because *B. enteritidis sporogenes* may be present in normal stools its presence in an effluent or in a water supply is of no moment. Passing over the fact that its numbers in normal stools are small when compared with the great numbers which are found in the excreta of patients suffering from acute diarrhœa, it is as idle to assert that because it may be present in normal stools its presence in an effluent or a water-supply is of no importance, as it would be to say that because *diplococcus pneumoniæ* (one of the most pathogenic micro-organisms known) may be present in normal human saliva, its presence elsewhere in nature is not fraught with any untoward significance. Moreover, it would seem to be the case that although the spores of *B. enteritidis sporogenes* may be found in the large intestine they are usually absent from the small intestine, except in cases of acute diarrhœa, when they are present in great abundance.

In the First Report a micro-photograph* is given showing the appearances produced in sterile milk when inoculated with a minimal quantity of sewage and thereafter heated to 80 °C for ten minutes and cultivated anaërobically at blood-heat. Briefly, the casein is precipitated and torn into irregular masses by the copious development of gas, and the whey presents a nearly transparent or slightly cloudy appearance. Now, even if we forget that these characteristic changes in the milk are microbial in origin, and discard altogether the question of the pathogenicity of the micro-organisms concerned in the process, and regard the change in the medium merely as a special phenomenon to be associated with the introduction of certain substances as opposed to others, the test still remains one of extreme value. For the *particulate matter* in as much as from 100 to 500 c.c. of a pure water does not in point of fact produce these changes when added to milk, whereas the addition of as little as $\frac{1}{100}$ to $\frac{1}{1000}$ c.c. of sewage does do so. Nor do we know of any substance which is not objectionable in character or which has not been associated *at some time* with matter of undesirable sort which can effect a similar transformation in milk.

The only possible objection that can be urged against the test is that the fact of *B. enteritidis sporogenes* being a sporing anaërobe weakens somewhat its usefulness as an indication of recent and therefore presumably specially dangerous pollution. Of course such a contention has little or no bearing on the experiments carried out in this inquiry.

It will be noted that the spores of *B. enteritidis* often exceeded in number the total number of spores of aërobic bacteria. The reason for this probably lies in the fact of *B. enteritidis* being an anaërobe. In nature anaërobic micro-organisms are usually found to be present in the spore-form, because doubtless it is but seldom that the conditions are favourable for their anaërobic growth, and if they were not capable of forming spores under adverse circumstances they might soon lose their vitality and die. Aërobic bacteria, on the other hand, commonly find in nature the conditions favourable for their continued growth and multiplication, and so are usually met with in the vegetative form. In surface soil, however, as has been already pointed out, the ratio of spores to bacteria is very high, because the physical conditions are frequently most unfavourable to microbial life.

On comparing the figures as regards the total number of bacteria and number of spores of *B. enteritidis* no definite correspondence can be made out between the two sets of figures either in the case of the crude sewage or in the effluents. In not a few cases when the total number of bacteria was large the number of spores of *B. enteritidis* was small and vice versâ.

It might perhaps have been anticipated that both in the case of the crude sewage and in the effluents there would be some measure of correspondence between the number of *B. coli* and the number of spores of *B. enteritidis sporogenes*. On comparing the two sets of figures it would seem that this is not the case; indeed, if there is any relation at all it is an inverse one. Thus dealing in the first place with the crude sewage only it will be noted that—

On ten different occasions the number of spores of *B. enteritidis* was very high, viz., at least 1,000 per c.c. On the corresponding dates the number of *B. coli* was five times below the average, only twice above, and on three occasions there were present the average number.

Taking next the five samples in which *B. coli* was present in great numbers, namely, 1,000,000 or more per c.c. In the corresponding samples the number of spores of *B. enteritidis* was about the average three times, less than the average once, and above the average once.

Taking next three samples in which *B. enteritidis* was present in small numbers, namely, at least 10 but less than 100 per c.c. On one of these dates *B. coli* was present in numbers exceeding one million per c.c., and in the two other samples *B. coli* was below the average.

* Fig. 14—Filtration of Sewage—First Report.

Next dealing with the ten samples in which *B. coli* was distinctly below the average, namely, those in which the number was 300,000 or less per c.c. In three of these samples the number of spores of *B. enteritidis* was over 1,000, five times the number was an average one, and in the remaining two the number was below the average.

Secondly, dealing with the effluents from the 4-foot coke-bed, a similar although perhaps less well marked want of correspondence between the number of B. coli and B. enteritidis is noticeable.

The records as regards the other coke-bed effluents are not very numerous and do not lend themselves readily to comparisons of the above sort.

In general summary of these results it may be said that—

(1) Although the total number of bacteria, the number of spores of aërobic microbes, the number of liquefying micro-organisms, the number of *B. coli*, and the number of spores of *B. enteritidis sporogenes* was, on an average, less in the effluents from the coke-beds than in the raw sewage, the reduction was not well marked, and frequently the number was actually greater in the effluents than in the corresponding samples of crude sewage.

(2) The 4-foot coke-bed yielded on the whole better results than the 6-foot primary and proved nearly as efficient as the 6-foot secondary coke-bed.

(3) There was no very definite evidence, so far as may be judged from these results, of any special selective* process being effected by the bacterial treatment of the sewage in the coke-beds, since the bacterial composition of the effluents was very much the same as that of the raw sewage.

(4) The number of microbes, both in the crude sewage and effluents, was always more than one million, but usually less than ten million per c.c.; the number of *B. coli* and spores of *B. enteritidis sporogenes* was usually more than 100,000, and at least 100, but less than 1,000, respectively, per c.c. More than one-tenth of the bacteria liquefied gelatine, and only about one in 20,000 was present in the spore form.

(5) As the bacterial composition of the effluents differed only slightly from the crude sewage, so far as this could be judged of by the records which have been enumerated, it cannot, in the absence of direct proof to the contrary, be safely considered that the effluents from the coke-beds are less dangerous than the raw sewage in their possible relation to disease.

It must, however, be remembered that in the present case there are practical points which first of all demand consideration. In this connexion it will not be out of place to quote from page 21 of the Second Report.

Thus in dealing with the general results obtained at Crossness it was said—"It must be admitted that the above results are not satisfactory from the bacteriological point of view, particularly when it is remembered that an effluent ought to be judged, not only by the percentage amount of purification effected, but also by the *actual state* it is in. Yet it is to be considered that these results assume a different complexion when viewed side by side with the chemical data.

"It has been shown in Division I. of this Report that the percentage purification, as judged from the dissolved oxidisable matter removed by the treatment, was on an average 50 per cent., and that the suspended matter was entirely removed. It has been stated that the results thus obtained surpass considerably those yielded by chemical treatment and appear to justify the claims put forward by the supporters of the biological treatment of sewage, especially since, so far as can be seen, no nuisance or danger arises as a result of the treatment.

"In the body of the Report a number of reasons are given, showing that it is unwise in the present state of our knowledge to recklessly condemn an effluent on bacteriological ground alone, without full knowledge of all the requirements of the case. In the attempt to treat sewage on biological lines it is to be noted that the solution of the suspended matter and even the considerable destruction of putrescible matters by microbial agencies afford sufficient ground for justifying the process, at all events as a preliminary measure. Whether this preliminary treatment is to be supplemented by further treatment, either by passage through other coke-beds, or by land irrigation or by any other method, is a matter largely dependent on circumstances.

"In the present case there are practical points which first of all demand consideration, and although it may be most desirable to obtain an effluent chemically pure and bacteriologically above suspicion of danger it is to be thought of that an effluent not altogether satisfactory in one or other, or even in both, of these respects may yet fulfil all necessary requirements without passing out of the range of practicability. In certain cases it may be imperative to obtain an effluent bacteriologically sound, but it does not follow that a similar result is urgently called for in other cases, as, for example, where an effluent is turned into a watercourse which is not used for drinking purposes, and which already may contain practically all the bacteria that are found in sewage.

"It might reasonably be argued that where an effluent is turned into a river already grossly polluted and below the lowest level of "intake" for waterworks purposes, the chemical state of such effluent was (from the practical point of view, at all events) of possibly even greater importance than the bacteriological. Some such state of things pertains in the case of London sewage and the river Thames. Here the initial consideration is to avoid fouling the river with

* That, however, some selective process is at work in the coke-beds need hardly be doubted. For example, raw sewage contains little or no oxidised nitrogen, whereas the effluents from bacterial beds contain nitrites, and nitrates often in considerable amount. This alteration in the chemical state of the liquid is brought about by nitrifying bacteria, and it is highly probable that these particular microbes multiply and accumulate in the coke-beds, and that the effluents from *mature* coke-beds contain more nitrifying organisms than the crude sewage. Some experiments of a tentative character which I have carried out seem to support this hypothesis.

putrescible matters to such an extent as to constitute a grave public nuisance. From this point of view it is evident that an effluent rich in putrescible matter is not permissible, but it is not as certain that an effluent rich in bacteria is equally to be condemned on practical grounds."

Methods.—For a description of the various methods employed the Report itself must be consulted (pages 22, 23, 24, 25, 27). Here it is permissible only to give the amounts of crude sewage or effluents to be added to the nutrient media in order to obtain the best results with the different processes.

Total number of bacteria—From $\frac{1}{100,000}$ to $\frac{1}{10,000}$ c.c.	Gelatine plate cultures, incubated at 20° C.*
Spores of aërobic bacteria—From $\frac{1}{10}$ to 1 c.c.	Gelatine plate cultures. Cultures previously heated to 80° C. for 10 minutes. (Incubated at 20° C.)
Liquefying bacteria—From $\frac{1}{100,000}$ to $\frac{1}{10,000}$ c.c.	*Surface* gelatine plate cultures. (Incubated at 20° C.)
B. coli—From $\frac{1}{100,000}$ to $\frac{1}{10,000}$ c.c.	*Surface* phenol (0·05 per cent.) gelatine plate cultures. (Incubated at 20° C.)†
Spores of B. enteritidis sporogenes—$\frac{1}{10,000}$; $\frac{1}{1,000}$; $\frac{1}{100}$; $\frac{1}{10}$ c.c.	Milk cultures, heated to 80° C. for 10 minutes, and cultivated anaërobically. (Incubated 37° C.)‡

The Biological Treatment of Sewage (*Section I., pages* 18-20, *Second Report*).

In speaking of the discoveries which have paved the way towards a scientific knowledge of the true nature of putrefactive processes, it was said that—

"One of the most important discoveries of recent times was that made by Schlœsing and Muntz in 1877. They proved that nitrification, or the oxidation of ammonia to nitric acid, is due to the vital activity of bacteria, and thus carried a stage further the important discovery by Schwann and Schultze (1839) that micro-organisms are the true agents of decomposition. Later, Winogradsky and others described and isolated, in pure culture, nitrifying organisms."

"Pasteur, following up the researches of Cagniard and Schwann, demonstrated, in 1857, the relation between lactic, acetic, and butyric fermentations and special organisms."

In discussing the aim and object of the biological treatment of sewage it was pointed out that—

"In nature the following cycle of transformation takes place. Dead organic matter decays as the result of the vital activity of bacteria, and ammonia is liberated. The nitrifying organisms bring about the oxidation of the ammonia, first to nitrous and then to nitric acid. These acids by reaction upon the bases, always present, form nitrites and nitrates, and these nourish the living plant. While the nitrogen is undergoing these changes, the carbon of the organic matter is converted into carbonic acid, and the hydrogen mainly into water. To some extent also the nitrogen and hydrogen are liberated in the free gaseous state."

Further, that—

"The organic matters found in sewage are partly in suspension and partly in solution, and sewage contains in itself the necessary living germs for the destruction of both these forms of organic matter. The aim and object of the biological treatment of sewage is to render soluble by microbial agencies the solid matters; and to split up by the action of living bacteria both the matter thus dissolved and organic compounds which were originally in solution into their simpler elements. In the final process of purification, these substances should undergo oxidation induced by the life processes of nitrifying organisms, and an effluent should be produced which is free from putrescible matter and contains only inorganic or mineral substances."

Two of the most remarkable phenomena to be observed in the study of biological coke-beds are (1) the almost complete removal of the suspended matters, and (2) the production of effluents which, although they usually still contain a quite appreciable amount of oxidisable organic matter, are, as a rule, *non-putrescible* so far, indeed, as this may be judged of by storing them in (a) completely filled and stoppered bottles and (b) partially filled and stoppered bottles.

It appears quite certain that the non-putrescible character of many effluents from bacterial coke-beds is not due to the absence of putrefactive bacteria. This is, of course, very evident from the numerous records which have been given of the bacterial composition of the Crossness effluents. In particular, the following paragraph (page 27, Second Report) is worth quoting—

"In experiments 9 and 10 (col. 5, Table I.) it was sought to discover the smallest amount of crude sewage and of effluent which in broth cultures at 20° C. would produce growth, indol reaction and offensive smell. No growth occurred in either case, when as little as 0,0000001 c.c. was inoculated into the broth: but when 0·000001 c.c. was used, growth occurred both in the case of the crude sewage and of the effluent, and the cultures had an offensive smell and gave indol reaction."

Probably the explanation lies, in part at all events, in a change in the *character* of the organic matter still remaining in the effluents. Possibly also the liquid acquires some quality inhibiting the putrefactive bacteria from exerting their putrescent effect.

Some stress was laid upon the fact that in certain cases "it may not be necessary to attempt the complete purification of the sewage, the solution of the suspended matters and partial destruction of the putrescible matters being all that is urgently called for, as, for example, where the

* In illustration of such cultures see Plate 1, fig. No. 2, First Report.
† " " Plate 1, fig. No. 1, First Report.
‡ " " Plate 1, fig. No. 14, First Report.

effluent is of relatively small bulk and is turned into a stream which is not used for domestic purposes (as is the case in the lower Thames) or else when the effluent is to be subsequently treated by land irrigation." And it was asserted that "the mere solution of the great mass of the suspended matters by bacterial agencies, which is, perhaps, common to all the different processes at present under trial, is a sufficient vindication of the enormous advantage to be gained by the biological treatment of sewage."

In conclusion reference was made to the systems of sewage disposal advocated by Messrs. Scott-Moncrieff, Cameron, Ducat, Dibdin and Thudichum, etc.

In Table I. (pages 28 to 31) the results were given of the bacteriological examination of Crossness crude sewage, the effluent from the 4-foot coke-bed, the effluent from the 6-foot coke-bed, and the effluent from the laboratory vessel (effluent from 6-foot coke-bed again treated in the laboratory at Crossness).

Most of the results recorded in this table have already been summarised, but it is worthy of note that besides searching for B. enteritidis and B. coli the attempt was also made to estimate the number as well as the character of other microbes present in the crude sewage and effluents, and that notes under this heading are recorded in the table.

Thus, the micro-organism called "*sewage proteus*"* was found to be present in great numbers (usually more than 100,000 in 1 c.c.) both in the crude sewage and effluents.

In Table 2 (pages 32-33) the results were shown of the bacteriological examination of the effluents from the Crossness and Barking Outfall Works and of the water of the River Thames. As regards the effluents from the Barking and Crossness precipitation tanks it may be said that they were no better, if, indeed, they were not worse than average samples of crude sewage. As regards Thames water, samples were taken at Greenhithe and Barking in such a way as to avoid, as far as this was possible, the influence of sewage discharge. These samples in their bacterial composition resembled dilute crude sewage. Samples were also collected high up the river, namely (1) between Sunbury and Hampton, just above the intake of the Southwark and Vauxhall Water Company (dry weather) and (2) at Twickenham (very wet weather). The former contained 40 gas-forming *B. coli* in 1 c.c. *B. enteritidis sporogenes* was present in 300 c.c. (1 c.c. of the culture killed a guinea-pig in less than 24 hours), but not in 100 c.c. The latter contained 100 gas-forming *B. coli*, and at least 10, but less than 100 spores of *B. enteritidis* per. c.c.

Thus it will be seen that Thames water at Barking and Greenhithe was no better than dilute crude sewage, and even as high up as near Hampton and Twickenham showed distinct evidence of pollution of the most objectionable kind.

These experiments were undertaken with a two-fold object.

In the first place to show that the effluents from the chemical precipitation tanks were no better, if, indeed, they were not worse than the effluents from the bacterial coke-beds, and secondly to demonstrate the fact that Thames water is already grossly polluted, and contains practically all the bacteria to be found in the effluents.

In section V. (pages 33-40) a description was given of some of the bacteria found in the crude sewage and in the effluents from the coke-beds.

In illustration of the Report there were 14 diagrams, 24 micro-photographs, and 4 diagrammatic drawings.

3.—SUMMARY OF THE CONTENTS OF THE SUPPLEMENT TO THE SECOND REPORT.†

In this Report a description was given of the results of the bacteriological examination of the deposit which accumulates on the coke of the coke-beds. The Report covered work carried out during May, June, and July, 1899.

A sample of the deposit from the coke-bed at Barking contained 1,800,000 microbes; and at least 10,000 but less than 100,000 spores of B. enteritidis sporogenes per gramme. Further, two mice inoculated with small portions of the deposit died of tetanus.

Stained, as for tubercle, a large number of "acid-fast" bacteria were found in the deposit. Other samples of deposit from the same and from other coke-beds were also found to contain these bacteria; and when crude sewage and effluents from coke-beds were centrifugalised and the deposit stained a similar result was obtained. Experiments on animals were negative with one exception; in this case the animal died of true tuberculosis.

In concluding the report it was said that—

I. In crude sewage, in bacterial coke-beds, and in the effluents from bacterial beds there are certain bacteria which, after being stained with hot carbol fuchsin, resist decolorisation with 33 per cent. nitric acid.

II. Some of these "acid-fast" bacteria cannot, with certainty, be morphologically distinguished from the *tubercle bacillus*.

III. In one instance a guinea-pig inoculated with the deposit accumulating on the coke of a bacterial bed died, and presented on examination the appearance of death from tubercle infection, and sections of its organs, when appropriately stained, showed the presence of numerous *tubercle bacilli*.

In illustration of the Report there were 10 micro-photographs and 1 coloured drawing.

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* A full description of the morphological and biological characters of this bacillus is given on pages 36 and 37 of the Second Report.

† Supplement to the Second Report. Notes on the deposit which accumulates on the coke fragments of the coke-beds at Crossness.

II.—THE EXPERIMENTS ON BACTERIAL TREATMENT AT BARKING.

It will be remembered that in the First Report the results were given of the examination of nine samples of Barking crude sewage. In the Second Report the results of the bacterial treatment of the sewage in coke-beds at Crossness were given. Here it is proposed to deal with somewhat similar experiments carried out at Barking.

I.—THE COKE AND RAGSTONE BEDS. *

The beds were four in number, namely, two of coke (coarse and fine), and two of ragstone (coarse and fine).

Some of the experiments with the effluents as regards their effect on animals are recorded elsewhere (experiments on animals, p. 68), and it will be remembered that the Supplement to the Second Report dealt chiefly with the deposit accumulating upon the coke in the coke-beds at Barking.

The effluents were chiefly examined for the presence of *B. enteritidis sporogenes*, and the results obtained in this direction are given in the form of a Table. But on March 16, 1899, a sample of Barking crude sewage, and the effluents from the fine ragstone-bed and the fine coke-bed were further examined for the total number of bacteria and number of *B. coli*. The results were as follows:—

Barking crude sewage ...	10.000,000 bacteria in 1 c.c. ...	600,000 *B. coli* in 1 c.c.
Effluent from fine ragstone-bed	4,000,000 bacteria in 1 c.c. ...	500,000 *B. coli* in 1 c.c.
	(60 per cent. reduction.)	(16 per cent. reduction.)
Effluent from fine coke-bed ...	1,800,000 bacteria in 1 c.c. ...	300,000 *B. coli* in 1 c.c.
	(82 per cent. reduction.)	(50 per cent. reduction.)

The following is a Table of the results as regards *B. enteritidis sporogenes* (Klein)—

TABLE 1.—NUMBER OF SPORES OF B. ENTERITIDIS SPOROGENES (KLEIN).

Date.	Barking crude sewage.	Effluents from the coke and ragstone beds at Barking.			
		Coke.		Ragstone.	
		Coarse.	Fine.	Coarse.	Fine.
1899					
Jan. 26	+ ·01 and ·001 c.c	...	+ ·01 and ·001 c.c.	...	+ ·01; — ·001 c.c.
Feb. 2	+ ·01 and ·001 c.c.	+ ·01; — ·001 c.c.	+ ·01; — ·001 c.c.	+ ·01 and ·001 c.c.	+ ·01 and ·001 c.c.
9	+ ·01 and ·001 c.c.	+ ·01; — ·001 c.c.	+ ·01; — ·001 c.c.	+ ·01 and ·001 c.c.	+ ·01; — ·001 c.c.
15	+ ·01 and ·001 c.c.	+ ·01 and ·001 c.c.	+ ·01 and ·001 c.c.	+ ·01 and ·001 c.c.	+ ·01 and ·001 c.c.
Mar. 8	+ ·01 c.c.... ...	+ ·01 c.c.... ...	+ ·01 c.c.... ...	+ ·01 c.c.... ...	+ ·01 c.c.
16	+ ·01 c.c.... ...	...	— ·01 c.c.... ...	...	+ ·01 c.c.
Apr. 13	+ ·01 c.c.... ...	— ·01 c.c.... ...	— ·01 c.c.... ...	+ ·01 c.c.... ...	— ·01 c.c.

The sign + signifies the presence and the sign — the absence of the spores of *B. enteritidis sporogenes*.

These results are shown in graphic form in Diagram 1.

It might have been anticipated that the fine beds would have produced a significant alteration in the number of spores of this pathogenic anaërobe. Such, however, was not the case, and although the number in the effluents was usually less than in the corresponding samples of crude sewage, the reduction was not very well marked, and was not, moreover, a constant feature. There did not seem to be any striking difference between the coarse and fine beds, or between the two kinds of material (coke and ragstone) as regards the number of spores of *B. enteritidis*.

2.—THE DOUBLE COKE-BEDS.

These coke-beds are known as—

The primary coarse coke-bed, series A
The secondary ,, ,, ,,
The primary ,, ,, ,, B
The secondary fine ,, ,,

A description of these beds will be found in the Chemical Division of the Report.

From October 16, 1899, to January 17, 1900, the new beds at Barking were under bacteriological observation.

The results obtained will be dealt with briefly as follows—

(*a*) TOTAL NUMBER OF BACTERIA (GELATINE AT 20° C.).

The number of micro-organisms in the crude sewage and effluents is given in the following Table—

* A description of these beds will be found in the Chemical Division of the Report.

Table 2.—Total number of bacteria in 1 c.c.

Date.	Barking crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B
1899.					
October 16 ...	7,200,000	1,700,000	800,000	...	...
23 ...	5,440,000	1,500,000	...	...	900,000
November 1 ...	8,800,000	2,640,000	2,000,000	...	...
7 ...	7,060,000	...	...	1,070,000	400,000
13 ...	3,680,000	...	1,180,000	910,000	...
28 ...	10,400,000	...	...	4,800,000	2,640,000
December 5 ...	...	...	1,480,000	4,520,000	1,000,000
12 ...	...	...	2,240,000	2,900,000	1,420,000
1900.					
January 3 ...	...	2,880,000	3,970,000	...	2,530,000
17 ...	...	...	1,760,000	2,000,000	1,220,000

These results are shown in graphic form in Diagram 2.

It is to be noted that on four occasions one or other of the effluents contained less than one million microbes per c.c., and on fifteen occasions not more than two millions. On November 7th the effluent from the secondary fine bed (series B.) contained only 400,000 microbes per c.c., as compared with 7,060,000 in the crude sewage, a reduction of over 94 per cent.

(*b*) Number of B. Coli or Closely Allied Forms.

The number of *B. coli* in the crude sewage and effluents is shown in the following Table—

Table 3.—Number of B. coli, or closely allied forms, in 1 c.c.

Date.	Barking crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B.
1899.					
October 16 ...	800,000	None in ·00001 c.c.	100,000	...	...
23 ...	200,000	800,000	...	...	None in ·00001 c.c.
November 1 ...	1,600,000	500,000	500,000	...	...
7 ...	1,200,000	...	...	200,000	None in ·00001 c.c.
13 ...	600,000	...	300,000	None in ·00001 c.c.	...
28 ...	200,000	...	...	200,000	100,000
December 5 ...	...	...	100,000	100,000	None in ·00001 c.c.
12 ...	...	...	100,000	400,000	400,500
1900.					
January 3 ...	...	200,000	100,000	...	200,000
17 ...	...	...	None in ·00001 c.c.	100,000	None in ·00001 c.c.

These results are shown in graphic form in Diagram 3.

It will be noted that on seven occasions one or other of the effluents contained no *B. coli* in ·00001 c.c. Usually, however, the effluents contained at least 100,000 *B. coli* per c.c.

Although there was evidence of a reduction in the number of *B. coli* in the effluents as compared with the crude sewage, the large number still remaining in the effluents must be regarded as very unsatisfactory from the epidemiological point of view.

(*c*) Number of Spores of B. Enteritidis Sporogenes.

The number of spores of *B. enteritidis sporogenes* is shown in the following Table—

Table 4.—Number of spores of B. enteritidis sporogenes (Klein).

Date.	Barking crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B.
1899	c.c.	c.c.	c.c.	c.c.	c.c.
Oct. 16	+ ·1, ·01 and ·001	+ ·1 and ·01; — ·001	+ ·1, ·01 and ·001	...	+ ·1 and ·01; — ·001
23	+ ·1, ·01 and ·001	+ ·1, ·01 and ·001	...	...	+ ·1 and ·01; — ·001
Nov. 1	+ ·1, ·01 and ·001	+ ·1, ·01 and ·001	+ ·1, ·01; — ·001	...	...
7	+ ·1, ·01 and ·001	...	...	+ ·1 and ·01; — ·001	+ ·1 and ·01; — ·001
13	+ ·01; — ·001	...	+ ·01; — ·001	+ ·01; — ·001	...
28	+ ·1 and ·01	...	...	+ ·1 and ·01	+ ·1 and ·01
Dec. 5	...	...	+ ·01; — ·001	+ ·01 and ·001	+ ·01; — ·001
12	...	...	+ ·01 and ·001	+ ·01 and ·001	+ ·01; — ·001
1900					
Jan. 3	...	+ ·01; — ·001	+ ·01 and ·001	...	+ ·01; — ·001
17	...	...	+ ·01	+ ·01	— ·01

The sign + signifies the presence and the sign — the absence of spores of *B. enteritidis sporogenes*.

These results are shown in graphic form in Diagram 4.

Although as a rule the effluents contained fewer spores of *B. enteritidis sporogenes* than the crude sewage, the reduction was not very well marked, and, moreover, was not a constant factor.

It cannot therefore be said that the biological processes at work in the coke-beds effected any significant alteration in the number of spores of this pathogenic anaërobe.

(*d*) Concluding Remarks.

On November 1st, 1899, *B. pyocyaneus** was isolated from $\frac{1}{1000}$ c.c. of the effluent from the second coarse bed (series A). It was very virulent, 1 c.c. of a 24 hours broth culture killing a guinea-pig in less than 24 hours. The same micro-organism was isolated in pure culture from the heart's blood, etc., of the animal. (See fig. 5, Plate II.)

On December 6th, 1899, three strains of "*sewage proteus*" were isolated from $\frac{1}{10000}$ c.c. of the effluent from the primary coarse bed (series B). They all liquefied gelatine very rapidly, they were actively motile, and produced "gas" in 24 hours in gelatine "shake" cultures. One of the strains killed a guinea-pig in 24 hours (1 c.c. of broth culture); another was not so virulent, ulceration occurred at the site of the inoculation, and the animal recovered; the third produced only a slight local reaction. This latter non-virulent strain of "*sewage proteus*" was used to inoculate the 13-feet coke-bed at Crossness (see page 75).

On November 1st, 1899, streptococci xix., xx., and xxi., were isolated from $\frac{1}{1000}$ c.c. respectively of the effluent from the primary coarse bed (series A), the effluent from the secondary coarse bed (series A), and the crude sewage. (See pages 66 and 67.)

During a considerable period of the enquiry, attention was directed to the study of the *thermophilic* bacteria. It was suggested to me, by Dr. Gordon, that a comparison of their numbers in the crude sewage and effluents might be of value.

These micro-organisms (*B. thermophilus* and its allies) have been shown to be present in the alimentary canal of human beings and mammals, in sewage, in sewage-contaminated waters, and in soil, but not in pure waters.

It was found that *thermophilic* bacteria § (capable of growing luxuriantly in broth culture at a temperature of 60-70° c.) were present in London crude sewage in abundance. They were also present, although usually in smaller proportion, in the effluents from the coke-beds.

It has been suggested that the presence or absence of these bacteria in a water supply might be employed as a test of potability. But, in my experience, *thermophilic* bacteria are present in numbers in soils *not recently* polluted and are often absent from waters known to be *freshly* contaminated with objectionable matters, waters, moreover, which, by more reliable and delicate bacteriological tests, can readily be shown to be dangerously polluted.

Certainly the presence of *thermophilic* bacteria in a water would lead one to suspect *gross* contamination, but their absence could hardly be regarded as testifying to purity or "safety."

Nevertheless, the test, as a rough indication of the probable biological quality of a liquid and as a means of comparing different liquids, e.g., crude sewage and bacterial effluents, is one not devoid of value.

III.—THE EXPERIMENTS ON BACTERIAL TREATMENT AT CROSSNESS.

1.—FURTHER EXPERIMENTS WITH THE EFFLUENTS FROM THE 4-FOOT, 6-FOOT (PRIMARY), AND 6-FOOT (SECONDARY) COKE-BEDS AT CROSSNESS.

In the Second Report the bacteriological results were brought up to the end of December, 1898. In the early part of the year 1899 some further experiments were carried out with the effluents from the 4-foot, 6-foot (primary), and 6-foot (secondary) coke-beds. These took the form of comparative determinations of the number of spores of anaërobic bacteria in the raw sewage and in the effluents from the coke-beds.

Number of Spores of Anaërobic Bacteria in Crossness Crude Sewage and in the Effluents from the Coke-beds.

The effect of the bacterial treatment of the raw sewage in coke-beds as regards the number of spores of *anaërobic* bacteria was to a considerable extent covered by the comparative determinations of the number of spores of *B. enteritidis sporogenes* in the raw sewage and in the effluents, carried out since February, 1898. Nevertheless, it was considered advisable to supplement those records with a series of experiments dealing with the number of spores of anaërobic bacteria of all kinds in the raw sewage and in the effluents capable of growing at 37° C. in agar under anaërobic conditions.

Table 5.—Number of spores of anaërobic bacteria in 1 c.c. [*Agar at* 37° *C.*]

Date.	Crossness crude sewage.	Effluent from 4 ft. coke-bed.	Effluent from 6 ft. primary coke-bed.	Effluent from 6 ft. secondary coke-bed.
1899.				
January 11 ...	1,988	720	920	No record
18 ...	304	380	424	224
25 ...	424	516	232	336
February 1 ...	201	100	191	197
8 ...	The growths spread over the surface of the medium, preventing accurate counting.			
15 ...	148	212	160	124
22 ...	262	128	196	156

The agar tubes were boiled for half-an-hour, rapidly cooled to 80° C., inoculated with the sewage or effluent, and heated to 80° C. for 10 minutes. The contents were next poured into plates, and these were immediately placed in an air-tight chamber containing a freshly-prepared mixture of pyrogallic acid and potassium hydrate solution. These results are shown in graphic form in Diagram 5.

* See fig. 5. This micro-organism (*B. Pyocyaneus*) must not be confused with the ordinary liquefying fluorescent bacillus (*B. fluorescens liquefaciens*) of sewage, soil and water. *B. fluorescens liquefaciens* does not grow, or only imperfectly, at *blood-heat*, and is not virulent; and differs in a number of other important respects from *B. Pyocyaneus*.

§ Figs. 9 and 10 show the morphological appearance of *B. Thermophilus* or an allied form. The micro-organism represented in the micro-photographs was isolated from London crude sewage: it grew luxuriantly at a temperature of 60–70° C.

Excluding the results obtained on January 11th, as the figures are abnormally high, and there is no record on that date for the 6-foot secondary coke-bed, the averages are as follows—

Average number of spores of anaërobic bacteria in five samples of Crossness crude sewage, and in five comparative effluents from the 4-foot, 6-foot (primary), and 6-foot (secondary) coke-beds, 268; 267; 240; and 207 per c.c. respectively.

It will be seen from these results that the bacterial treatment of the crude sewage in the coke-beds did not effect any marked alteration in the number of spores of anaërobic bacteria. Indeed the number in the effluent from the 4-foot coke-bed was practically the same as in the raw sewage, and in the case of the effluents from the 6-foot (primary) and 6-foot (secondary) coke-beds the reduction was only 10 and 22 per cent. respectively.

Pressure of other work for the Council made it impossible to study fully the morphological and biological characters of the different kinds of anaërobic bacteria isolated in pure culture from the anaërobic agar plates; and the notes under this heading are of too fragmentary a character to make it advisable to place them on record. So far as could be made out there was no difference as regards species of microbes between the anaërobic cultures made from the crude sewage and those made from the effluents from the coke-beds.

The appearance presented by the colonies (superficial and deep) under a low power of the microscope is shown diagrammatically in Plate V., fig. C. So far as could be judged by observation under a low power of the microscope and by making sub-cultures the number of spore-forming anaërobes of different species was not great. As regards growth in anaërobic milk culture some of the microbes isolated from the agar plate cultures produced precipitation of the casein, with abundant development of gas, the whey remaining nearly transparent, or presenting only a slightly cloudy appearance; others produced no visible change even after several days incubation at 37° C.; others again gave rise to an appearance resembling slow peptonization, beginning just below the surface, and gradually extending downwards in cylindrical fashion.

A rise or fall above or below the mean in the number of the spores of anaërobic bacteria in the crude sewage was usually associated with a similar increase or decrease in the number of spores of anaërobes in the effluents from the 4-foot, 6-foot (primary), and 6-foot (secondary) coke-beds.

In conclusion, and as an addition to the records of the bacterial composition of Crossness crude sewage, it may be worthy of note that the number of spores of anaërobic bacteria (agar at 37° C.) in Crossness crude sewage is usually between 200 and 300 per c.c.

2.—EXPERIMENTS WITH THE EFFLUENTS FROM THE 13-FOOT COKE-BED AT CROSSNESS.*

The chief results obtained will be given under the following headings—

(*a*) Total number of bacteria (gelatine at 20° C.).
(*b*) Number of *B. coli* or closely allied forms.
(*c*) Number of spores of *B. enteritidis sporogenes* (Klein).
(*d*) Number of bacteria capable of growing in agar at 37° C.

(*a*) Total Number of Bacteria (gelatine at 20° C.).

The results as regards the total number of bacteria are given in the following table—

Table 6.—Showing the total number of bacteria in 1 c.c.

Date.	Crossness crude sewage.	Effluent from the 13 ft. coke-bed at Crossness.
1899.		
March 22	5,000,000	2,000,000
May 11	4,600,000	3,000,000
July 5	7,200,000	16,000,000
August 2	4,110,000	8,000,000
September 1	2,240,000	1,940,000
7	3,910,000	1,490,000
13	11,170,000	5,040,000
19	9,580,000	6,750,000
27	5,000,000	4,100,000
October 4	4,300,000	5,320,000

These results are shown in graphic form in Diagram 6.

It is to be noted that the average numbers of microbes in the crude sewage and in the effluent from the 13-foot coke-bed were 5,711,000 and 5,364,000 per c.c. respectively. This means a reduction of only 6 per cent., the reason being that on July 5th and August 2nd the effluent contained a much larger number of micro-organisms than the raw sewage. On all other occasions, with one exception (October 4th), the effluent contained fewer bacteria than the corresponding samples of crude sewage. A rise or fall above or below the mean in the total number of microbes in the raw sewage was coincident with a similar increase or decrease in the number of germs in the corresponding samples of effluent on eight occasions. In the remaining three cases this relationship was not observed.

* A description of this bed will be found in the Chemical Division of the Report.

(*b*) Number of B. Coli or Closely Allied Forms.

The results, as regards *B. coli*, are given in the following table—

Table 7.—Number of B. coli or closely allied forms per c.c.

Date.	Crossness crude sewage.	Effluent from the 13 ft. coke-bed at Crossness.
1899.		
March 22	100,000	100,000
May 11	700,000	200,000
July 5	None in 0·00001 c.c.	None in 0·00001 c.c.
August 2	900,000	400,000
September 1	400,000	200,000
7	300,000	100,000
13	500,000	900,000
19	1,900,000	900,000
27	500,000	300,000
October 4	600,000	600,000

These results are shown in graphic form in Diagram 7.

The Table shows that on one occasion the number of *B. coli* was greater in the effluent from the 13-foot coke-bed than in the corresponding sample of raw sewage. In nearly all the other cases the crude sewage contained the larger number. Nevertheless, although on an average the bacterial treatment of the crude sewage effected a reduction in the number of *B. coli*, the number actually remaining in the effluents was very large—usually more than 100,000 per c.c.

(*c*) Number of Spores of B. Enteritidis Sporogenes (Klein).

The results, as regards *B. enteritidis sporogenes*, are given in the following table—

Table 8.—Showing the number of spores of B. enteritidis sporogenes (Klein).

Date.	Crossness crude sewage.	Effluent from the 13 ft. coke-bed at Crossness.
1899.		
March 22 ...	+ ·01 c.c.	+ ·01 c.c.
April 12 ...	+ ·01 and ·001 ; — ·0001 c.c. ...	+ ·01 ; — ·001 c.c.
19 ...	+ ·01 ; — ·001 c.c.	+ ·01 ; — ·001 c.c.
27 ...	+ ·001 ; — ·0001 c.c.	+ ·01 ; — ·001 c.c.
May 4 ...	+ ·01 and ·001 ; — ·0001 c.c. ...	+ ·01 ; — ·001 c.c.
11 ...	+ ·01 ; — ·001 c.c.	— ·01 c.c.
18 ...	+ ·01 ; — ·001 c.c.	— ·01 c.c.
July 5 ...	+ ·01 ; — ·001 c.c.	+ ·1 ; — ·01 c.c.
August 2 ...	+ ·1 and ·01 ; — ·001 c.c. ...	+ ·1 and ·01 ; — ·001 c.c.
September 1 ...	+ ·1, ·01 and ·001 c.c.	+ ·1 and ·01 ; — ·001 c.c.
7 ...	+ ·1 and ·01 ; — ·001 c.c. ...	+ ·1, ·01 and ·001 c.c.
13 ...	+ ·1, ·01 and ·001 c.c.	+ ·1, ·01 and ·001 c.c.
19 ...	+ ·1, ·01 and ·001 c.c.	+ ·1 and ·01 ; — ·001 c.c.
27 ...	+ ·1 and ·01 ; — ·001 c.c. ...	+ ·1 and ·01 ; — ·001 c.c.
October 4 ...	+ ·1 and ·01 ; — ·001 c.c. ...	+ ·1 and ·01 ; — ·001 c.c.

The sign + signifies the presence and the sign — the absence of the spores of *B. enteritidis sporogenes*.

These results are shown in graphic form in Diagram 8.

It is to be noted that although the number of spores of *B. enteritidis sporogenes* was frequently less in the effluents from the 13-feet coke-bed than in the corresponding samples of crude sewage, the *actual* number of spores remaining in the effluent after the bacterial treatment of the sewage was very large—usually at least 100, but less than 1,000 in 1 c.c.

(*d*) Number of Bacteria capable of growing in Agar at 37° C.

In the Second Report (page 27) it was pointed out that—"In experiments 3 and 5 (col. 5, Table I.) the number of bacteria in the crude sewage capable of growing at 37° C. in agar was estimated. The numbers were 1,260,000 and 1,171,000 per c.c., as compared with 3,670,000 and 6,400,000 obtained by gelatine plate cultivation at 20° C. A similar experiment (experiment 4) with the effluent from the 4-foot coke-bed gave 1,630,000 (agar at 37° C.) as compared with 4,100,000 (gelatine at 20° C.) bacteria per c.c."

At the period (May, 1898) when these experiments were carried out the pressure of other important work prevented a series of experiments being carried out on the above lines. It, however, was considered important to extend these observations at as early a date as possible.

The following Table gives the number of bacteria (agar at 37° C.) in Crossness crude sewage and in the effluent from the 13-foot coke-bed. It also gives, for comparative purposes, the number of bacteria (gelatine at 20° C.) in the corresponding samples.

Table 9.—Showing the number of bacteria (agar at 37° C. and gelatine at 20° C.) in seven samples of Crossness crude sewage, and seven samples of the effluent from the 13 ft. coke-bed.

Date.	Number of bacteria in 1 c.c.			
	Crossness crude sewage.		Effluent from the 13 ft. coke-bed.	
	Agar at 37° C.	Gelatine at 20° C.	Agar at 37° C.	Gelatine at 20° C.
1899.				
August 2 ...	2,660,000	4,110,000	2,540,000	8,000,000
September 1 ...	1,660,000	2,240,000	670,000	1,940,000
7 ...	1,530,000	3,910,000	930,000	1,490,000
13 ...	6,830,000	11,170,000	5,210,000	5,040,000
19 ...	5,270,000	9,580,000	4,020,000	6,750,000
27 ...	2,600,000	5,000,000	2,400,000	4,100,000
October 4 ...	2,510,000	4,300,000	3,850,000	5,320,000

These results are shown in graphic form in Diagram 9.

The Table shows that the average number of bacteria (agar at 37° C.) in the crude sewage and in the effluent was 3,294,444 and 2,802,857 respectively per c.c., showing a reduction of about 14 per cent. Further, that the average number of bacteria (gelatine at 20° C.) in the crude sewage and in the effluents was 5,758,571 and 4,662,857 respectively per c.c., i.e., a reduction of about 19 per cent.

Comparing the figures 3,294,444 (agar at 37° C.) and 5,758,571 (gelatine at 20° C.) it is to be noted that the difference is 42 per cent., hence more than one-half of the number of bacteria capable of growing in gelatine at 20° C. can likewise grow in agar at 37° C. When a similar comparison is made as regards the effluents from the 13-foot coke-bed the difference is 39 per cent.

It is evident from these results that the bacterial treatment of the sewage in the coke-beds did not effect any marked reduction in the number of *blood-heat* organisms; indeed, the reduction was less as regards these germs than as regards the bacteria growing in gelatine at 20° C.

Although gelatine is doubtless a more favourable medium than agar for the growth of bacteria of all sorts, it is not the difference of nutrient medium, but of temperature which chiefly accounts for the difference in the numbers under the two sets of conditions. As a matter of fact the number of bacteria in sewage capable of growing at 37° C. is both actually very great and is very great also in relation to the total number of microbes growing at the ordinary temperature, the reason apparently being that so many of the micro-organisms found in sewage are derived from the intestinal discharges of animals, e.g., *B. coli*, which has been shown to be present in numbers usually exceeding 100,000 per c.c.

In pure waters the number of "*blood-heat*" bacteria is usually small, and their ratio to the number of germs growing at the ordinary temperature is likewise small.

Although a large number of "*blood-heat*" bacteria is considered a bad sign, it must not be supposed that all the different species of microbes capable of growing at 37° C. are harmful. Many found in sewage and elsewhere in nature are, so far as we know, quite unobjectionable, e.g., *B. subtilis*, *B. mesentericus*, *B. mycoides*, etc. On the other hand others are decidedly objectionable and may be pathogenic, e.g. *B. coli* and *B. proteus* (certain forms), and some are definitely pathogenic, e.g., *B. pyocyaneus*. In the Second Report (page 27) it was stated—"A cultivation of *B. pyocyaneus* isolated from a sample of Crossness crude sewage proved to be extremely virulent. Thus 1 c.c. of a twenty-four hours' broth culture (at 37° C.) injected subcutaneously into a guinea-pig killed the animal in less than twenty-four hours, and the organism was recovered in pure culture from the heart's blood, spleen, etc."

On November 1, 1899, *B. pyocyaneus** was isolated from $\frac{1}{1000}$ c.c. of the effluent from the secondary coarse bed (series A) at Barking. A guinea-pig injected subcutaneously with 1 c.c. of a twenty-four hours' broth culture (at 37° C.) died in less than twenty-four hours, and the same micro-organism was isolated in pure culture from its heart's blood.

In the light of this result (apart from the numerous records contained in this and previous Reports of equal or greater significance) it is strange that many still consider the effluents from coke-beds and in general from bacterial processes, non-pathogenic.

So far as may be judged by a rise or fall above or below the mean, the figures show that both as regards the crude sewage and the effluents there was a decided parallelism between the number of bacteria growing in agar at 37° C. and the number growing in gelatine at 20° C. Similarly, a rise or fall above or below the mean in the number of bacteria capable of growing in agar at 37° C. in the crude sewage was nearly always coincident with a rise or fall in the number of microbes in the corresponding effluents from the 13-foot coke bed.

In conclusion, and by way of addition to the chief results which have been obtained during the progress of the inquiry, it is to be noted that the number of bacteria capable of growing in agar at blood-heat in Crossness crude sewage is usually over three millions per c.c., and more than one-half of the number of microbes growing in gelatine at 20° C. It must be admitted that the 13-foot coke-bed at Crossness yielded very unsatisfactory results from the bacteriological point of view.

* See fig. 5.

Thus although the effluents usually contained fewer bacteria and less of *B. coli* and spores of *B. enteritidis sporogenes* than the crude sewage, the reduction was not well marked, and, indeed, was immaterial from the epidemiological point of view, considering the *actual* number still remaining. For, as has been already pointed out, the effluents usually contained more than one million microbes, more than 100,000 *B. coli*, and at least 100 but less than 1,000 spores of *B. enteritidis sporogenes* per c.c.

IV.—STREPTOCOCCI IN THE BARKING AND CROSSNESS CRUDE SEWAGE AND IN THE EFFLUENTS FROM THE BACTERIAL COKE-BEDS.

In the First Report* under the heading of "Methods" it was stated that streptococci and staphylococci were to be looked for in agar cultures incubated at blood-heat. In the Second Report† when dealing with the "species of micro-organisms" it was noted that streptococci and staphylococci were present both in the crude sewage and in the effluents from the coke-beds. In the present Report it is proposed to give the results of the work carried out in this direction. It is to be noted that the records extend back to November, 1898.

Although attention was directed to the study of staphylococci as well as streptococci it is the latter class of germs which will be considered here. One reason why staphylococci are considered of relatively less importance than streptococci in connection with the work is that the former *as a class* are hardy germs, whereas the latter as a class are delicate micro-organisms. The bearing of this remark will be shown presently.

My chief reasons for considering this portion of the sewage inquiry of special and peculiar importance are briefly as follows—

Speaking of streptococci *as a class* it may be said that—

(1) They are among the most *pathogenic* of all the bacteria which are at present known;

(2) They are *delicate* germs, and very readily lose their vitality and die;

(3) They are present in the *intestinal discharges* of animals. In human fæces there may be more than 1,000 present in one gramme;

(4) They are absent from water and soil,§ except in those cases where there has been *recent* contamination with sewage or other substances equally objectionable in character.

It will presently¶ be shown that both in crude sewage and in effluents from coke-beds streptococci are present in great abundance—usually more than 1,000 in 1 c.c.—and that the bacterial treatment of the raw sewage effected no marked alteration in their numbers.

Now if the streptococci found in such numbers in the crude sewage and in the effluents are derived from the intestinal contents of animals, and are delicate germs, and are also pathogenic, the position is a somewhat serious one.

In the first place, as regards *experiments on animals*, the records show that the streptococci were more often non-pathogenic than pathogenic in the case of mice. Numerous records of the effects on mice of streptococci isolated from soil-polluted water, sewage, and sewage effluents which I have since obtained and which are not included in this Report show that as a rule, and when obtained from the above sources, they are not pathogenic. Still it must not be lost sight of that the absence of pathogenic effect on mice does not necessarily imply the absence of disease-producing property in other animals. Nor does it prove that the streptococci were previously non-pathogenic. Further, it is conceivable that some alteration in the conditions surrounding these streptococci might, if they had been pathogenic in the past, restore to them all their original virulence.

Speaking in general terms, however, it may be said that the streptococci found in nature outside the animal body, e.g., in polluted soils and water, in sewage and sewage effluents are not as a rule pathogenic to mice.

Secondly, as regards the assertion that streptococci are *delicate germs* and readily lose their vitality and die. Although this certainly accords with our experience of streptococci isolated from the human subject, particularly in cases of disease and septic infection, it might well be the case that some at all events of the streptococci occurring in nature outside the animal body, e.g., in sewage, are hardy germs and are capable not only of resisting death, but also of multiplying under favourable conditions. In all probability this is true to some extent, yet it is not without significance that certain of the streptococci about to be described when subcultured in gelatine and incubated at 20° C. showed little or no appreciable growth at the end of thirteen days. And some of the streptococci that I have isolated from sewage-polluted water, etc., have proved their delicacy by refusing to grow when subcultures were not carried out at short intervals. Thus on several occasions the study of a streptococcus has been prematurely cut short by the death of the organism. Still further it has been a matter of common observation that subcultures made from colonies in agar plate cultures of sewage which (colonies) under a low power of the microscope revealed their real nature by the occurrence of separate loops of cocci at the periphery, frequently showed *no growth*, the microbes (streptococci) having already lost their vitality. In opposition to this it might be urged that certain of the streptococci in sewage are in reality hardy germs, but that the

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* Filtration of sewage (First Report), page 3, B. 6 (*e*).

† Bacterial treatment of crude sewage (Second Report), page 27, III., 4 (*c*).

§ The significance of streptococci in water and soil is dealt with by me in Reports to the Local Government Board. Report of the Medical Officer, Local Government Board, 1898–9.

¶ In this and succeeding paragraphs I purposely anticipate what follows.

nutrient media ordinarily employed by bacteriologists is not the most suitable kind of pabulum for them. It is to be noted as possibly affording some support to this view that if sewage be centrifugalised and the deposit stained* the microbes taking the stain are not, as might have been anticipated, chiefly bacillary in form, but appear either as cocci or rods, so short and rounded at their ends as to simulate cocci. Moreover, these cocci are frequently arranged in long chains (streptococci).

Nevertheless, it may be said with a fair measure of confidence that some, at all events, of the streptococci in sewage and in sewage effluents are delicate germs, and readily lose their vitality and die.

The importance to be attached to these observations is great. If in the bacterial treatment of sewage micro-organisms of presumably feeble vitality pass through the coke-beds in practically unaltered numbers, then there is every reason to fear that those microbes which we know are distinctly pathogenic to man, and which may be either habitually present in sewage or present as chance and occasional visitors, and some of which are believed to be in comparison hardy germs, would likewise be unaffected by the biological processes at work in the coke-beds.

In previous Reports I have stated "that the balance of evidence points to the probability that some, at all events, of the pathogenic organisms are crowded out in the struggle for existence in a nutritive medium, containing a mixed bacterial flora, their vitality being weakened or destroyed by the enzymes of the saprophytic species." This broad statement was permissible then, but now, in the light of these results, it can hardly be considered altogether satisfactory.

Lastly, as regards the *source* of streptococci, it has been said that they are present in the intestinal discharges of animals, and are absent from waters and soils except in cases of *recent* and objectionable pollution. It might perhaps be argued that streptococci may have a wide distribution in nature, and if so that their presence in a substance, be it soil or sewage or water, is of little or no significance. Against this view it may be pointed out that if they are delicate germs it is unlikely that they would survive, much less multiply in nature unless the conditions were ideally favourable. Further, that although I have frequently isolated streptococci from as minute a quantity of sewage as 0·001 c.c., and of human fæces as 0·001 gramme, I have repeatedly failed to demonstrate their presence in comparatively large amounts of pure water and pure soils.||

These facts have led me to advocate this test (presence of streptococci) as a valuable one in the bacterioscopic examination of waters.† Not, indeed, that the absence of streptococci implies "safety," but that their presence affords strong evidence of *recent* and therefore presumably specially dangerous pollution.

In conclusion I venture to assert that this test is of extreme value in judging sewage effluents from the biological point of view. And I am strongly of opinion that if an effluent contains streptococci in practically unaltered numbers, or even in reduced numbers where such reduction is only in the same proportion as the other microbes also present are reduced, then such an effluent is, as regards danger to health, no better in the first case than raw sewage and no safer in the latter than crude sewage slightly diluted, but otherwise unaltered in its possible capacity of giving rise to disease.

The following is a description of some of the streptococci isolated from London crude sewage and from the effluents from the bacterial beds.

1. *Name—Streptococcus I.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—November 16th, 1898.
4. *Morphology*—Stains well by Gram's method. The chains of cocci are usually short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
    (*a*) *Agar* (37° C.)—Small transparent colonies showing wavy granulation. The colonies are irregular in shape, and at the edges the loops of cocci can be made out§.
    (*b*) *Gelatine* (20° C.)—Small transparent colonies, circular in shape, and faintly granular. The edges are *clean* and no loops of cocci are visible. No liquefaction.
6. *Streak cultures*—
    (*a*) *Agar* (37° C.)—Small transparent colonies, faintly granular.
    (*b*) *Gelatine* (20° C.)—A white, transparent film-like growth, which on close observation is seen to be made up of separate colonies. No liquefaction occurs.
7. *Gelatine at* 37° C.—No diffuse cloudiness. Flocculent little masses with cirrhus-like extensions.¶
8. *Broth cultures* (37° C.)—The broth remains quite transparent. Flocculent masses with cirrhus-like extensions are formed in the fluid. Old broth cultures show at the foot of the tube a white granular mass, the medium itself being quite transparent. On shaking the tube, granular masses of various sizes rise in the clear liquid and rapidly subside again to the bottom.‡
9. *Litmus milk cultures* (37° C.)—Strong acidity and solid clot in 24 hours.
10. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of broth culture remained apparently unaffected.

1. *Name—Streptococcus II.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness 6 ft. primary coke-bed effluent.
3. *Date*—November 16th, 1898.
4. *Morphology*—Stains well by Gram's method. Very short chains as a rule, but occasionally a chain of medium length may be found.

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* Deposit upon the coke in the coke-beds. (Supplement to the Second Report.) See also Plate II., Figs. 6, 7, and 8 of this Report.

|| I have, however, found streptococci in abundance in waters and soils *recently* polluted with sewage.

† Report of the Medical Officer, Local Government Board, 1898–99.

§ Plate IV., fig. A. (*a*). ¶ Plate IV., fig. B. (*a*). ‡ Plate IV., fig. B. (*b*).

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—

(*a*) *Agar* (37° C.)—Small transparent circular faintly-granular colonies with *firm* edges. No loops of cocci are visible at the periphery.*

(*b*) *Gelatine* (20° C.)—Small transparent faintly-granular colonies, circular in shape with *clean* edges. Old colonies may present a nucleated appearance. No appearance of separate loops of cocci at the periphery of the colonies. No liquefaction.†

6. *Streak cultures*—

(*a*) *Agar* (37° C.)—Minute transparent colonies. The colonies are situated so close together as to appear at first sight like a continuous film.

(*b*) *Gelatine* (20° C.)—Almost no growth, even after 13 days.

7. *Gelatine at* 37° C.—Granular cloudiness, with a white granular deposit at the foot of the tube.‡

8. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube white viscous growth, which on shaking the tube, rises in the form of a spiral.§

9. *Litmus milk cultures* (37° C.)—In 2 day's acidity; in 4 days, strong acidity but no clot; 7th day, still no clot; 25th day, still no clot.

10. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of a 4 days' broth culture died on the 7th day. Microscopic preparations made from the kidney juice showed the presence of cocci, sometimes arranged as diplo-cocci, and showing an appearance as of a surrounding capsule. This was not very distinct, however. Agar plate cultures were made from the spleen, and a streptococcus was isolated, which differed somewhat from the one above described. It produced diffuse cloudiness in broth and diffuse granular cloudiness in gelatine at 37° C. Milk was rendered strongly acid and clotted.

1. *Name—Streptococcus III.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length; most of them are short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—

(*a*) *Agar* (37° C.)—Minute transparent faintly-granular colonies. Most of the colonies are circular with a *clean* edge. Some are irregular in shape with a ragged edge resembling somewhat Streptococcus I.¶

(*b*) *Gelatine* (20° C.)—Small transparent colonies, roughly circular in shape with firm edges. The colonies are faintly granular, and show no separate loops of cocci at the periphery. No liquefaction.

6. *Streak cultures*—

(*a*) *Agar* (37° C.)—The growth appears at first sight like a continuous delicate film, but is in reality composed of numerous minute transparent and separate colonies.

(*b*) *Gelatine* (20° C.)—Colonies are somewhat large for a streptococcus: they are roughly circular in shape, and have a granular appearance. No liquefaction.

7. *Gelatine at* 37° C.—Granular cloudiness at the foot of the tube. Throughout the medium granular cloudiness and slight diffuse cloudiness as well.

8. *Broth cultures* (37° C.)—Diffuse cloudiness throughout the medium.

9. *Litmus milk cultures*—Acidity, but no clot in 24 hours. Later, strong acid but no clot (14th day).

10. *Remarks*—1 c.c. of a 2 days' broth culture injected subcutaneously in a mouse produced no apparent effect.

1. *Name—Streptococcus IV.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains by Gram's method. Chains of cocci of variable length; usually short, however.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—

(*a*) *Agar* (37° C.)—Colonies very similar to Streptococcus III.

(*b*) *Gelatine* (20° C.)—As practically no growth occurred in gelatine streak cultures, no gelatine plates were made.

6. *Streak cultures*—

(*a*) *Agar* (37° C.)—Growth resembles both Streptococcus I. and Streptococcus III.

(*b*) *Gelatine* (20° C.)—Practically no growth, even after 13 days.

7. *Gelatine at* 37° C.—Granular deposit at foot of tube and granular cloudiness throughout the medium, but no diffuse cloudiness.||

8. *Broth cultures* (37° C.)—Diffuse cloudiness. Deposit at the foot of the tube coherent in masses unlike Streptococcus III.

9. *Litmus milk cultures* (37° C.)—Distinct acidity, but no clot (11th day).

10. *Remarks*—1 c.c. of a 2 days' broth culture injected subcutaneously in a mouse. The mouse died on 9th day. Cover glass specimens made from kidney juice, peritoneal fluid, &c., showed the presence of cocci and diplococci (appearance suggestive of surrounding capsule, but not very distinct). Agar plate cultures were made from the organs, but the plates were crowded with putrefactive bacteria, and no streptococci were isolated.

1. *Name—Streptococcus V.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains by Gram's method. Short chains and chains of medium length.

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* Plate IV., fig. A (*b*). † Plate IV., fig. A (*c*). ‡ Plate IV., fig. B (*c*). § Plate IV., fig. B (*d*).
¶ Plate IV., fig. A (*d*). || Plate IV., fig. B (*e*)

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Appearances very similar to Streptococcus III., *i.e.*, some colonies circular and granular with *clean* edges; others more or less irregular in shape with ragged edges. Apparently, however, fewer colonies of irregular shape and ragged edges than in the cases of Streptococci III. and IV.
   (*b*) *Gelatine* (20° C.)—As there was practically no growth in gelatine streak cultures, no gelatine plate cultures were made.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—Growth somewhat similar in appearance to Streptococcus III.
   (*b*) *Gelatine* (20° C.)—Practically no growth (13th day).
7. *Gelatine at* 37° C.—Appearance very like Streptococcus III.
8. *Broth cultures* (37° C.)—Diffuse cloudiness.
9. *Litmus milk cultures*—Distinct acidity, but no clot (11th day).

1. *Name—Streptococcus VI.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length, but usually short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Small transparent granular colonies, usually circular in shape. Most of the colonies have a firm edge, but in some of them the edge has a ragged appearance.
   (*b*) *Gelatine* (20° C.)—No record.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth resembles Streptococcus I.
   (*b*) *Gelatine* (20° C.)—By the 13th day the colonies have attained a fair size: they are granular, and at the edge have a lobed and fissured appearance. The colonies are white, but towards the centre they are yellowish-white in colour. No liquefaction.
7. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube white viscous growth, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures* (37° C.)—Very slight acidity, no clot (10th day).

1. *Name—Streptococcus VII.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—November 29th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length, but usually short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Small more or less circular colonies, transparent and granular. Most of the colonies have a firm edge, but in others the edge is broken up and uneven in character.
   (*b*) *Gelatine* (20° C.)—As there was practically no growth in gelatine streak cultures (13th day at 20° C.), no gelatine plate cultures were made.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—No record.
   (*b*) *Gelatine* (20° C.)—Practically no growth (13th day at 20° C.).
7. *Broth cultures* (37° C.)—Some diffuse cloudiness, and at the foot of the tube granular masses as in Streptococcus I.
8. *Litmus milk cultures* (37° C.)—Slight acidity, but no clot (10th day).

1. *Name—Streptococcus VIII.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 6 ft. primary coke-bed at Crossness.
3. *Date*—December 9th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length.
5. *Agar plate cultures* (37° C.) (under a low power, Leitz, 3 objective, 1 ocular)—Small transparent granular colonies with firm edges and roughly circular in shape.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth appears as a thin transparent greyish-white film, which on close examination is seen to be made up of minute separate colonies.
   (*b*) *Gelatine* (20° C.)—Colonies are transparent and granular-looking. No liquefaction (13th day).
7. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube a white deposit, which rises in the form of a spiral on shaking the tube.
8. *Litmus milk cultures* (37° C.)—Strong acidity, but no clot (11th day).
9. *Remarks*—1 c.c. of broth culture injected subcutaneously into a guinea-pig. The animal remained apparently unaffected.

1. *Name—Streptococcus IX.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 6 ft. secondary coke-bed at Crossness.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci usually short, but some of medium length.
5. *Agar plate cultures*, 37° C. (under a low power, Leitz, 3 objective, 1 ocular)—The majority of the colonies are circular in shape with firm edges. They are small, granular and transparent looking.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth at first sight looks like a continuous white film, but on close inspection it is seen to be made up of numerous separate minute transparent colonies.
   (*b*) *Gelatine* (20° C.)—Minute transparent colonies, more or less circular in shape. No liquefaction.

7. *Broth cultures* (37° C.)—Diffuse cloudiness; white deposit, at the foot of the tube; on shaking the tube deposit rises in the form of a spiral.

8. *Litmus milk cultures* (37° C.)—Feeble acidity in two days. Later, distinct acidity, but no clot (11th day).

9. *Remarks*—1 c.c. of a 24 hours' (at 37° C.) broth culture injected subcutaneously in a mouse. The mouse died on the 5th day. Cocci present in juice of spleen and kidneys. From the spleen a pure culture of a streptococcus was obtained, forming chains of medium length, and which differed somewhat from the above. In broth the fluid remained clear, and at the foot of the tube the growth occurred as a white conglomerate mass. In gelatine at 37° C. very slight diffuse cloudiness, and at the foot of tube a loose flocculent cloudy growth. In gelatine plate cultures, colonies irregular in shape with uneven edge, wavy granulation well marked.

1. *Name*—*Streptococcus X.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 6 ft. secondary coke-bed at Crossness.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of medium length.*
5. *Agar plate culture*, 37° C. (under a low power, Leitz, 3 objective, 1 ocular)—Irregularly-shaped colonies with broken up edge. Transparent with wavy granulation, and at edge loops of cocci can be made out.†
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth is made up of numerous minute separate transparent colonies which at first sight appears like a continuous filmy growth.
   (*b*) *Gelatine* (20° C.)—By the 13th day colonies of varying size. They are very irregular in shape, with lobed and fissured borders and delicate filamentous extensions like fine sea-weed. The colonies are white, but towards centre the colour is yellowish-white.
7. *Broth cultures* (37° C.)—Diffuse cloudiness; at foot of tube white viscous deposit which on shaking the tube rises in spiral form.
8. *Litmus milk cultures* (37° C.)—In two days distinct acidity, but no clot; 11th day still no clot.

1. *Name*—*Streptococcus XI.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci of variable length, but usually short.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Most of the colonies minute, transparent and granular with firm edge.
   (*b*) *Gelatine* (20° C.)—The majority of the colonies are nearly circular in shape: they are transparent looking and faintly granular with firm edge. No liquefaction.§
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth at first sight appears like a continuous film, but is really made up of separate minute transparent colonies.
   (*b*) *Gelatine* (20° C.)—Small transparent faintly granular colonies. No liquefaction (13th day).
7. *Broth cultures* (37° C.)—Diffuse cloudiness; at the foot of the tube viscous white deposit, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures* (37° C.)—No visible change, even after 11 days' incubation.

1. *Name*—*Streptococcus XII.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. A streptococcus forming very short chains.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Small circular colonies with firm edge, transparent and granular looking.
   (*b*) *Gelatine* (20° C.)—The colonies are usually circular: they are faintly granular and transparent looking. The edge is *clean*. No liquefaction.¶
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The colonies are rather large for a streptococcus; they have a granular and transparent appearance.
   (*b*) *Gelatine* (20° C.)—The mass of the growth appears as a continuous film; but at the edge and upper portion of the streak the colonies are separate and are small with a granular transparent appearance. No liquefaction.
7. *Gelatine at* 37° C.—A granular white deposit forms at the foot of the tube, and the gelatine throughout is full of minute granular specks.
8. *Broth cultures* (37° C.)—The broth is clear, but on sides of tube white cirrhus-like growth, and at foot of tube viscous white conglomerate mass.
9. *Litmus milk cultures* (37° C.)—Slight acidity, but no clot (11th day).

1. *Name*—*Streptococcus XIII.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. It was difficult to determine whether this microbe was a streptococcus or a staphylococcus. Finally, it was classed as a streptococcus.

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* Plate I., fig. 1. † Plate IV., fig. A (*e*).
§ Plate IV., fig. A (*f*).
¶ Plate IV., fig. A (*g*).

5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—The large colonies are roughly circular in shape and the smaller ones irregular. Wavy granulation is well marked, and at the edge of the colonies separate loops of cocci can be made out. The colonies are small and transparent-looking.*
   (*b*) *Gelatine* (20° C.)—The colonies are very irregular in shape, and at the edge loops of cocci may be made out. They are small and transparent, and show a coarse wavy granulation.†
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth is composed of separate colonies which are transparent and granular-looking, and are rather large for a streptococcus.
   (*b*) *Gelatine* (20° C.)—By the 13th day the colonies have attained a fair size; they are irregular in shape and tend to run into each other. No liquefaction.
7. *Gelatine at* 37° C.—Resemble Streptococcus XII.
8. *Broth cultures* (37° C.)—The cloudiness is not well marked and is somewhat granular in character. On shaking the tube gently viscous white masses with cirrhus-like extensions rise from the foot and float throughout the liquid.
9. *Litmus milk cultures* (37° C.)—Slight acidity, but no clot (15th day).
10. *Potato cultures* (37° C.)—No visible growth (8th day).

1. *Name—Streptococcus XIV.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 15th, 1898.
4. *Morphology*—Stains well by Gram's method. The chains are short and tend to cohere in masses. The cells are somewhat irregular in shape.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—The colonies are small, nearly circular in shape, with a fairly firm edge. They are granular and transparent-looking.
   (*b*) *Gelatine* (20° C.)—The colonies are roughly circular in shape. Wavy granulation is well marked. The edge may have a slightly ragged appearance, but no separate loops of cocci can be made out. No liquefaction.§
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The colonies are separate, granular and transparent-looking, but are of rather a large size for a streptococcus.
   (*b*) *Gelatine* (20° C.)—Resembles Streptococcus XII. No liquefaction (13th day).
7. *Gelatine at* 37° C.—Resembles Streptococcus XII.
8. *Broth cultures* (37° C.)—The broth remains nearly transparent. At the foot of the tube the growth collects as a viscous white mass.
9. *Litmus milk cultures* (37° C.)—Distinct acidity, but no clot (11th day).

1. *Name—Streptococcus XV.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci are usually short, but some are of medium length.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Small, transparent, circular, granular colonies with firm edge.
   (*b*) *Gelatine* (20° C.)—Small colonies of circular shape and with clean edge. They may present a nucleated appearance. They are granular and transparent-looking. No liquefaction.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—A barely visible white film, which on close observation is seen to be made up of separate colonies (minute and transparent-looking).
   (*b*) *Gelatine* (20° C.)—Resembles somewhat Streptococcus XII. No liquefaction (13th day).
7. *Broth cultures* (37° C.)—Diffuse cloudiness. At the foot of the tube a white viscous deposit, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures* (37° C.)—In two days, distinct acid but no clot; 5th day, ditto; 11th day, ditto.
9. *Remarks*—1 c.c. of a 24 hours' broth culture (37° C.) injected subcutaneously into a mouse. The mouse died on the 5th day. Microscopic preparations were made from the peritoneal fluid, &c. Cocci were present, but also many putrefactive bacilli. Agar plates made from the spleen were overgrown with putrefactive organisms, and no streptococci could be isolated.

1. *Name—Streptococcus XVI.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Long chains of cocci matted together in masses.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Minute transparent colonies, usually of circular shape, and showing wavy granulation. No separate loops of cocci at periphery.
   (*b*) *Gelatine* (20° C.)—Small, circular, transparent and granular-looking colonies. No liquefaction.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—Thin, delicate film, which on close examination is seen to be made up of minute separate colonies.
   (*b*) *Gelatine* (20° C.)—Resembles Streptococcus X.
7. *Broth cultures* (37° C.)—Broth remains perfectly transparent. At foot of tube white conglomerate mass.
8. *Litmus milk cultures* (37° C.)—Second day, no visible change; 5th day, slight acidity, but no clot. Later, acidity more decided. No clot 11th day.

* Plate IV., fig. A (*h*). † Plate IV., fig. A (*i*). § Plate IV., fig. A (*j*).

1. *Name—Streptococcus XVII.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from 4 ft. coke-bed at Crossness.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Chains of cocci short. The cells tend to cohere in masses simulating a staphylococcus.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Small, granular and transparent-looking colonies, nearly circular in shape. The edge of the colonies has a ragged appearance, but no separate loops of cocci can be made out.
   (*b*) *Gelatine* (20° C.)—Minute colonies of circular shape, showing faint granulation. The colonies are transparent-looking and some have a nucleated appearance. The edge is firm and no separate loops of cocci are visible. No liquefaction.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—The growth presents no special characters worthy of note.
   (*b*) *Gelatine* (20° C.)—Resembles somewhat Streptococcus XII. No liquefaction.
7. *Broth cultures* (37° C.)—Broth remains quite transparent. On sides of tube cirrhus-like, streaky, white growth. At foot of tube, viscous white deposit.*
8. *Litmus milk cultures* (37° C.)—In two days, distinct acid, but no clot; 5th day, ditto; 11th day, ditto.

1. *Name—Streptococcus XVIII.*
2. *Source*—$\frac{1}{1000}$ c.c., Crossness crude sewage.
3. *Date*—December 21st, 1898.
4. *Morphology*—Stains well by Gram's method. Short to medium chains.
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Colonies circular with firm edge; transparent and faintly granular.
   (*b*) *Gelatine* (20° C.)—Most of the colonies seem to be made up of two portions, a granular, irregularly-shaped, darker portion, and a more transparent and larger portion, which is less granular. Some of the colonies, however, appeared to be composed of a collection of delicate loops like S. Longus type. No liquefaction.†
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—Resembles somewhat Streptococcus XV.
   (*b*) *Gelatine* (20° C.)—On the 13th day the growth resembled Streptococcus XII., but in a few places delicate filamentous extensions like fine seaweed may be seen. No liquefaction.
7. *Broth cultures* (37° C.)—Diffuse cloudiness, and at foot of tube viscous white deposit, which on shaking the tube rises in the form of a spiral.
8. *Litmus milk cultures*—No visible change, even after 11 days' incubation.

1. *Name—Streptococcus XIX.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from the primary coarse bed (series A) at Barking.
3. *Date*—November 1st, 1899.
4. *Morphology*—Stains well by Gram's method. The chains of cocci are of medium length.§
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Irregularly-shaped, transparent colonies, showing well-marked wavy granulation. At the edge of some of the colonies separate loops of cocci are clearly visible.
   (*b*) *Gelatine* (20° C.)—Small transparent colonies, showing faint wavy granulation. Usually circular in shape with clean edge. No liquefaction.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—No record.
   (*b*) *Gelatine* (20° C.)—Minute, transparent, circular colonies. No liquefaction.
7. *Broth cultures* (37° C.)—Some diffuse cloudiness, but granular cloudiness as well. On sides of tube, streaky, cirrhus-like, white growth.
8. *Litmus milk cultures* (37° C.)—In two days strong acid, but no clot; 4th day, ditto.
9. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. broth culture remained apparently unaffected.

1. *Name—Streptococcus XX.*
2. *Source*—$\frac{1}{1000}$ c.c., effluent from the secondary coarse bed (series A) at Barking.
3. *Date*—November 1st, 1899.
4. *Morphology*—Stains well by Gram's method. Resembles Streptococcus XIX.¶
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Minute, transparent colonies, nearly circular in shape with clean edge. Wavy granulation very faint. Some of the colonies are more granular-looking and have a slightly frayed edge.
   (*b*) *Gelatine* (20° C.)—Resembles Streptococcus XIX.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—No record.
   (*b*) *Gelatine* (20° C.)—Very similar to Streptococcus XIX., but the colonies are more transparent-looking.
7. *Broth cultures* (37° C.)—Resembles Streptococcus XIX.
8. *Litmus milk cultures*—In two days, strong acid but no clot; 4th day, strong acid but no clot.
9. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of a broth culture was apparently unaffected.

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* Plate IV., fig. B (*f*).
† Plate IV., fig. A (*k*).
§ Plate I., fig. 2.
¶ Plate I., fig. 3.

1. *Name—Streptococcus XXI.*
2. *Source*—$\frac{1}{1000}$ c.c., Barking crude sewage.
3. *Date*—November 1st, 1899.
4. *Morphology*—Stains well by Gram's method. The chains of cocci are usually short, but occasionally long chains may be seen.*
5. *Plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—
   (*a*) *Agar* (37° C.)—Minute, transparent, faintly granular-looking colonies with clean edge. Usually circular in shape.
   (*b*) *Gelatine* (20° C.)—Small transparent colonies showing only very faint granulation. Colonies are circular with slightly wavy border. No liquefaction.
6. *Streak cultures*—
   (*a*) *Agar* (37° C.)—No record.
   (*b*) *Gelatine* (20° C.)—Resembles Streptococcus XIX. and XX., but the colonies are smaller and more transparent-looking.
7. *Broth cultures* (37° C.)—Abundant diffuse cloudiness; at foot of tube viscous white deposit.
8. *Litmus milk cultures* (37° C.)—Strong acidity, but no clot.
9. *Remarks*—A mouse inoculated subcutaneously with 1 c.c. of broth culture was apparently unaffected.

General Summary of the above results, as regards the presence of Streptococci in the Crude Sewage and in the Effluents from the Bacterial Beds.

Name—It is apparent that many of the streptococci resembled *S. Brevis* and some *S. Longus*. Moreover, certain of them, if they had been isolated from a septic case in the human subject, would almost certainly have been classed as *S. Pyogenes*. In the present state of our knowledge, it has been thought best to merely register them for descriptive purposes as Streptococcus I., II., III., &c. Of course, many of them resembled each other so closely as to suggest identity of species or, at all events, close kinship. But the results seem to indicate that streptococci are not only more numerous, but that the number of different species is much greater than has hitherto been supposed. A great many microbes isolated from crude sewage and effluents from bacterial beds are not included in the above list, because, on studying their morphological and biological characters, they seemed to resemble staphylococci (a class of germs as numerous in sewage apparently as streptococci, but probably of relatively less importance) more closely than streptococci. The line, however, dividing these two classes of germs is by no means a sharp one, and it is possible that a few microbes have been included in the above list which really ought to be placed in an intermediate position, *i.e.*, between the streptococci and staphylococci.

Source—In each case the streptococci were isolated from as minute a quantity as $\frac{1}{1000}$ c.c. of Barking or Crossness crude sewage, or the effluents from the coke-beds at Barking and Crossness. There did not appear to be any significant alteration in the number of streptococci as the result of the bacterial treatment of the raw sewage.

Date—It is to be noted that the earlier records extend back as far as November, 1898.

Morphology—All stained well by Gram's method. The majority formed short chains, but in some the chains were of medium length, and in a few the chains were long. Sometimes the chains cohered together forming masses, thus simulating staphylococci. In such cases the biological characters of the microbes were closely studied before coming to a definite conclusion. [As a rule staphylococci grow more rapidly and produce a much more luxuriant and opaque growth on the surface of gelatine and agar than streptococci. Further, staphylococci not uncommonly liquefy gelatine. On the other hand, streptococci do not liquefy gelatine, and as a rule grow very slowly and form minute and transparent-looking colonies in agar and gelatine cultures.]

Temperature—It is to be noted that all the streptococci grew well at blood heat.

Agar and gelatine cultures—In most cases the colonies were very small, circular in shape, transparent-looking, and faintly granular, with a *clean* edge. Sometimes, however, the colonies showed coarse, wavy granulation, and were irregular in shape with a frayed edge, or showed at the periphery separate loops of cocci. It must not be lost sight of that some of the streptococci showed little or no appreciable growth when incubated at 20° C. for 13 days in gelatine streak culture.

Broth cultures—About 50 per cent. produced diffuse cloudiness with a viscous white deposit at the foot of the tube. In about 20 per cent. the broth remained quite clear, the growth appearing either as a conglomerate mass or else as masses with cirrhus-like extensions. In about 15 per cent. the cloudiness was granular in character with streaky cirrhus-like growths. In about 10 per cent. there was diffuse cloudiness

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* Plate I., fig. 4.

with a deposit at the foot of the tube coherent in granular masses. In about 5 per cent. a viscous white mass collected at the foot of the tube, the broth remaining transparent.

Litmus milk cultures—About 85 per cent. produced acidity but no clot. About 5 per cent. showed acidity and clot. About 10 per cent. produced no visible change.

Experiments on animals—Only a limited number of experiments were carried out. Sometimes a pathogenic effect was produced in mice, but most of the animals were apparently unaffected. An absence of pathogenic effect as regards mice does not necessarily imply freedom from disease-producing capability in respect of other animals. Moreover, some of these streptococci may have been highly virulent in the past, but have lost their pathogenic action. It is conceivable that these same streptococci might under certain conditions regain their full virulence.

It is apparent from these results that the type of streptococcus which is especially abundant in sewage is one presenting the following characters. For convenience of description it is permissible to call this microbe "*Sewage Streptococcus*." The following is a brief description of its chief morphological and biological characters —

1. *Name*—"*Sewage Streptococcus*."
2. *Source*—Barking and Crossness crude sewage and effluents from bacterial coke-beds.
3. *Abundance*—Usually more than 1,000 per c.c. of crude sewage and effluents.
4. *Temperature*—Grows well at blood heat.
5. *Morphology*—Stains well by Gram's method. The chains of cocci are usually short.
6. *Agar and gelatine plate cultures* (under a low power, Leitz, 3 objective, 1 ocular)—The colonies are small and transparent. They are nearly circular in shape with a *clean* edge. The granulation is faint. The colonies in agar are usually more granular and darker looking than in gelatine cultures. The gelatine is not liquefied.
7. *Streak cultures* (agar at 37° C. and gelatine at 20° C.)—The growth usually shows itself as a delicate white film, which on close observation is seen to be made up of numerous separate minute transparent-looking colonies. The gelatine is not liquefied.
8. *Broth cultures* (37° C.)—Abundant diffuse cloudiness. On gently shaking the tube a viscous white deposit rises from the foot of the tube in a spiral form.
9. *Litmus milk cultures* (37° C.)—Acidity, but usually no clot.
10. *Remarks*—Probably non-pathogenic to mice.

It will be understood that the above is a description not of a special micro-organism, but of the type of streptococcus most commonly present in crude sewage and in the effluents from the coke-beds.

V.—EXPERIMENTS ON ANIMALS.

Injection of Crude Sewage and Effluents into Guinea-Pigs.

The conclusions which have been arrived at as a result of the above experiments may be briefly stated as follows:—

I.—The subcutaneous injection of Barking and Crossness crude sewage into guinea-pigs (about 1—3 c.c. per 200 grammes weight) always produces a local reaction, and usually death in from 24 to 72 hours. If the guinea-pigs do not die within the first few days, although suppuration and ulceration may set in at the site of the inoculation, the animal usually eventually recovers completely. Sometimes the effluents from the coke-beds are more pathogenic than the raw sewage itself, but as a rule a somewhat larger dose of effluent is required to produce a fatal result. If the crude sewage or effluent be injected intra-peritoneally instead of subcutaneously, the animals usually die more quickly, and succumb to a smaller dose. There are, however, exceptions to this rule.

II.—If the injection of the crude sewage or effluent is not followed by fatal results within the first few days, the animal may occasionally die after the lapse of some weeks time, and on post-mortem examination show appearances simulating tubercle infection; but on closer study it will be found that death was really due to *pseudo-tuberculosis (B. pseudo-tuberculosis of Pfeiffer)*.

[It will be remembered, however, that in one case a guinea-pig inoculated with a portion of coke-deposit died from *true tuberculosis*. Supplement to Second Report.]

III.—When the animal dies rapidly (24—72 hours), virulent microbes, belonging to the class of *B. coli* and *B. proteus*, may readily be isolated from the blood or tissues of the animal.

IV.—If the crude sewage or effluent be previously heated to 100° C. for one hour, large doses may be injected without producing a fatal result. This would seem to show that the pathogenic effect of the sewage and effluents is not directly traceable to such of the intra-cellular and extra-cellular products of microbes as are capable of resisting this temperature.

[This temperature (100° C.) would change poisonous *active albuminoids* to non-poisonous *passive albuminoids*, and would also decompose *enzymes*; but it would not destroy the poisonous substances resulting from the decomposition of putrefying albuminoids known as *ptomaines*.]

V.—If the crude sewage or effluent be previously heated to 80° C. for ten minutes, a pathogenic effect may still be produced; but a much larger dose is usually required than where the liquid has not been so heated. Here death, when it occurs, is probably due to *B. enteritidis*

sporogenes, or, it may be, to anaërobic micro-organisms of the *malignant œdema* group. These results would seem to indicate that the pathogenic effect of sewage and sewage effluents is not usually or primarily due to micro-organisms present in spore form, since a much larger dose is required when the liquid has been previously heated to 80° C.; unless, indeed, these microbes possess an increased pathogenic power in the presence of other germs not present as spores.

VI.—If the crude sewage or effluent be filtered through a sterilised Pasteur's filter, very large doses of the filtrate fail to produce a pathogenic effect. This would seem to prove that it is not the extra-cellular products of the bacteria which by themselves produce the pathogenic result. But it is conceivable that filtration under the above conditions may render the bacterial products harmless where before they were noxious.

It is not proposed to give in detail the numerous experiments which have been carried out on animals; but a few experiments may be given by way of illustration.

February 22nd, 1899.

(*a*) 1 c.c. Barking crude sewage injected subcutaneously in guinea-pig (called g.p. i).

(*b*) 1 c.c. effluent from Barking fine ragstone-bed injected subcutaneously in guinea-pig (called g.p. ii).

(*c*) 1 c.c. effluent from Barking fine coke-bed injected subcutaneously in guinea-pig (called g.p. iii).

February 23rd—g.p. i poorly, with swollen belly; g.p. ii and iii fairly lively, with less abdominal swelling.

February 24th—g.p. i, moribund; g.p. ii and iii, in about the same condition as on the preceding day.

February 25th—g.p. i dead. On *post-mortem examination*, showed thickening of abdominal wall and œdema, but not much sanguineous exudation.

March 1st—g.p. ii and iii quite lively and well, except that g.p. ii had some abdominal ulceration.

The animals (g.p. ii and iii) eventually recovered completely from the effects of the injection.

March 1st, 1899.

(*a*) 1 c.c. Crossness crude sewage injected intra-peritoneally in guinea-pig (called g.p. i).

(*b*) 1 c.c. Crossness effluent from B single coke-bed injected intra-peritoneally in guinea-pig (called g.p. ii).

March 2nd—g.p. ii moribund, so killed.

March 3rd—g.p. i dead.

March 29th, 1899.

(*a*) 1 c.c. Barking effluent coarse ragstone-bed injected subcutaneously in guinea-pig (called g.p. i).

(*b*) 1 c.c. Barking effluent coarse coke-bed injected subcutaneously in guinea-pig (called g.p. ii).

(*c*) 1 c.c. Barking effluent fine ragstone-bed injected subcutaneously in guinea-pig (called g.p. iii).

(*d*) 1 c.c. Barking effluent fine coke-bed injected subcutaneously in guinea-pig (called g.p. iv).

(*e*) 1 c.c. Crossness effluent 13 ft. coke-bed injected subcutaneously in guinea-pig (called g.p. v).

April 1st—g.p. i and g.p. iv dead.

April 3rd—g.p. iii dead.

April 4th—g.p. ii and g.p. v apparently quite recovered from effects of the inoculation.

April 27th, 1899.

(*a*) 1 c.c. Crossness crude sewage injected subcutaneously in guinea-pig (called g.p. i).

(*b*) 1 c.c. Crossness effluent from 13 ft. coke-bed injected intra-peritoneally in guinea-pig (called g.p. ii).

(*c*) 1 c.c. Crossness crude sewage injected intra-peritoneally in guinea-pig (called g.p. iii).

(*d*) 1 c.c. Crossness effluent from 13 ft. coke-bed injected subcutaneously in guinea-pig (called g.p. iv).

April 29th—g.p. i dead.

May 1st—g.p. iii dead.

May 4th—g.p. iv. dead, g.p. ii apparently quite recovered from the effects of injection.

November 28th, 1899.

(*a*) Barking effluent from B 1 coke-bed, heated 80° C. for ten minutes. Two c.c. injected subcutaneously in guinea-pig (called g.p. i). The animal remained apparently unaffected.

December 1st, 1899.

(*a*) 3 c.c. Barking crude sewage injected subcutaneously in guinea-pig (called g.p. i).

(*b*) Same as (*a*), but crude sewage previously heated to 80° C. for ten minutes (called g.p. ii).

The dose was apparently too large, as both g.p. i and g.p. ii died, but the former died first.

December 12th, 1899.

(*a*) 1 c.c. Barking crude sewage injected subcutaneously in guinea-pig (called g.p. i).

(*b*) Same as (*a*), but sewage previously heated to 80° C. for ten minutes, and 2 c.c. injected (called g.p. ii).

(*c*) Same as (*a*), but sewage previously heated to 100° C. for one hour, and 4 c.c. injected (called g.p. iii).

(*d*) Same as (*a*), but sewage first filtered through a sterilised Pasteur's filter, and 10 c.c. of the filtrate injected.

All the animals recovered from the effects of the injection except g.p. i.

VI.—FINAL CONCLUSIONS.

Before giving the final conclusions from the biological point of view as to the value of the bacterial process in use at Barking and Crossness for treating London crude sewage, it is essential to first make some remarks of a general and introductory character; otherwise a totally erroneous impression might be formed, and it might even be considered that the conclusions arrived at after two years' close study of the subject were of such a nature as to condemn the process. Thus, if no note were taken of the chemical results and the practical side of the question and the bacteriological results were considered by themselves, and not read as they ought to be side by side with the chemical data, an impression might be gained which was not intended, and which was quite remote from the truth.

Many of the points about to be alluded to have been dealt with in previous Reports, but it is necessary to repeat them here for the reasons which have been stated.

I.—GENERAL CONCLUSIONS.

The Thames is a tidal river, and the "intakes" for waterworks purposes are situated high up the river and are "cut off" by "locks" from the influence of the sewage discharge at the Outfall Works.*

Although the bulk of London sewage is certainly very great the large size of the river Thames must also be considered, as also the proximity of the "Outfalls" to the sea and the huge body of water in the river at high tide.

The river water outside the influence of the discharges at the Outfall Works is already polluted and contains practically all the bacteria found in raw sewage.

The body of Thames water which may be supposed to be directly affected by the discharge of the effluents at Barking and Crossness is "brackish" and so could hardly be tolerated for drinking purposes even by individuals who are indifferent to the physical characters and biological composition of the water which they drink.

The bacterial coke-beds effect a reduction of at least 50, and it may be as much as 80 per cent. in the amount of dissolved oxidisable and putrescible organic matter in the raw sewage, as compared with 17 per cent. effected by the chemical treatment.

The effluents from the coke-beds are apparently non-putrescible.§

The suspended matters† in the crude sewage are practically entirely removed as a result of the biological treatment instead of only about 80 per cent. effected by the chemical treatment. And recent experiments seem to show that this result may be obtained without loss of capacity in the coke-beds if the sewage has undergone a previous process of rapid sedimentation.

In the biological treatment no chemicals are required, and no offensive sludge is produced.¶

Where an effluent is turned into a stream to be used for drinking purposes, the bacteriological results are manifestly of more importance than the chemical; but when, as in the present case, the river is not a potable one, and is already polluted, the converse probably holds good; i.e., the chemical state of the effluent is of primary, and the biological of secondary importance. In the first case the chief object is to guard against disease, and in the second case the main consideration is to avoid fouling the river with putrescible matters to such an extent as to constitute a grave public nuisance.

However desirable it may be to obtain an effluent chemically pure, and, at the same time, bacteriologically above suspicion of danger, a process which leads to the solution of the great mass of suspended matters in the raw sewage, which effects a striking reduction in the amount of putrescible matters, which avoids the use of chemicals and the accumulation of offensive sludge, which yields an apparently non-putrescible effluent, and which is at the same time practicable, is one which presents such singular advantages over chemical treatment, and which produces such satisfactory results in view of all the requirements of the case, that it would be idle to deny its value or attempt to minimise its usefulness simply because it falls short of a standard of absolute perfection.

Passing next to considerations which are purely biological in character, the following points are worthy of note.

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* It is assumed that no contamination of the *underground water* in the Thames valley takes place as a result of the pollution in the lower *reaches* of the river affecting distant sources of water supply (*e.g.*, deep wells). If in the future reliable evidence to the contrary should be forthcoming, then the whole question might require reconsideration.

§† It may be suggested that further evidence is required to show that an effluent apparently non-putrescible remains so under all conditions, and also that an effluent free, or nearly so, from suspended matter remains permanently in that condition. For it is conceivable that an effluent non-putrescible in itself might yet give rise to a putrescent effect when discharged into a stream, and that substances originally in solution might pass out of solution as the result, perhaps, of secondary degeneration. Nevertheless, from actual experiments carried out by the chemists in charge at the Outfall Works, as well as by observation of the state of the river, this would not seem to take place in the case of the discharge of the effluents at Barking and Crossness into the Thames.

¶ As regards this paragraph and the preceding ones, the Second Report (Division 1, Section 1, No. 5, page 7) may with advantage be consulted.

2.—BIOLOGICAL CONCLUSIONS.

Although the total number of bacteria, the number of spores of aërobic bacteria, the number of liquefying microbes, the number of *B. coli* and of spores of *B. enteritidis sporogenes* was, on an average, less in the effluents from the coke-beds than in the corresponding samples of crude sewage, the reduction was not well marked, and in some cases the effluents contained more micro-organisms than the sewage before treatment. Thus, while the chemical results were always satisfactory, the bacteriological results were usually quite the reverse, because the microbes producing the chemical changes passed through the coke-beds in practically unaltered numbers.

[The reasons for this state of things would seem to be that the process itself depends for its success on the vital activity of bacteria; that the fragments of coke are not fine enough to allow of the mechanical separation of the germs; that the products of the growth of the microbes, while they are self-injurious, are not sufficiently poisonous to destroy their life, although they, doubtless, exercise a restraining influence on the extent of the multiplication; and finally, that purification is not carried sufficiently far to exhaust all the assimilable pabulum in the liquid.

It has been pointed out in previous Reports that *B. coli* is an aërobic facultative anaërobic microbe of intestinal origin which may be pathogenic, and that *B. enteritidis sporogenes* (Klein) is a pathogenic anaërobe typical of excremental matters which appears to be causally related to certain cases of acute diarrhœa in the human subject, and whose cultures are extremely virulent to guinea-pigs.

Both in this and in previous Reports it has been stated that *B. coli* and the spores of *B. enteritidis sporogenes* are present in the effluents from the coke-beds in numbers usually exceeding 100,000 and 100 respectively per c.c. Further, it has been shown that a *proteus-like* germ ("*sewage proteus*") is present in abundance in the effluents—usually more than 100,000 per c.c. Some *strains* of this microbe are very virulent to guinea-pigs. Lastly, a highly virulent *strain* of *B. pyocaneus* has been isolated from so minute an amount as $\frac{1}{1000}$ c.c. of a Barking coke-bed effluent.

Further, the cultures made from the crude sewage and effluents were frequently compared side by side, yet no distinct differences could be made out between the two sets of cultures as regards the species of microbes.

[Of course this does not preclude the possibility of there having been a failure to detect points of difference not easily appreciable even to the trained observer. Still less does it mean that no selective process was in operation in the coke-beds. It is known that certain microbes, *e.g.*, the nitrifying germs, do not grow on the media ordinarily used by bacteriologists; and no doubt, as time goes on, the list will be greatly increased. The mere fact that the raw sewage contained little or no oxidised nitrogen while the effluents contained nitrites and nitrates, implies that nitrification was in progress, and doubtless the nitrifying germs were not only stored in the coke-beds, but were present in the effluents in greater number than in the raw sewage. Indeed, certain experiments which were carried out in this connection, but which are of too preliminary a character to merit inclusion in this Report, seemed to support this view.]

In the present Report records are given showing that *streptococci* presumably of intestinal origin pass through the coke-beds in practically unaltered numbers, and may be isolated from $\frac{1}{1000}$ c.c. or less of the effluents. And reasons are given which suggest somewhat strongly that if *streptococci* can resist the biological processes at work in the coke-beds there is small ground for believing that other germs of a dangerous kind, *e.g.*, the typhoid bacillus, will be destroyed.

Further, it has been stated in this Report that although the *products* of the bacteria in the effluents are not fatal even when large doses are injected subcutaneously into guinea-pigs, the effluents plus the contained bacteria are decidedly pathogenic and do not indeed differ in this respect materially from the raw sewage.

[A local reaction is always observed, and abscess formation and ulceration frequently result from the injections, although they do not necessarily prove fatal. When death occurs rapidly, the fatal result seems to be usually due to virulent *B. coli* or *B. proteus* or *B. enteritidis sporogenes*, or to microbes more or less closely allied to these germs. Doubtless, however, other microbes are also concerned in producing a pathogenic effect. Sometimes the animal apparently recovers, but eventually dies from *pseudo-tuberculosis* (*B. pseudo tuberculosis.*)]

In the Supplement to the Second Report it was shown that the deposit accumulating on the coke in the bacterial beds contained the spores of *B. enteritidis sporogenes* in great abundance, and also that two mice inoculated subcutaneously each with a small portion of the deposit died with all the characteristic symptoms of *tetanus*. Further, "*acid-fast*" *bacteria* were present in considerable numbers in the deposit, and they were also found in the crude sewage and effluents—particularly in the latter. The inference would seem to be that the "*acid-fast*" *bacteria* are stored in the coke-beds, and are habitually or occasionally washed away in the effluents.

[Although many of these "*acid-fast*" *bacteria* could not with certainty be morphologically distinguished from the *tubercle bacillus*, it was not claimed that they were *necessarily* the microbe of *tuberculosis*, alive or dead, virulent or non-virulent. But it was pointed out as a significant fact that in one instance a guinea-pig inoculated with the deposit from a bacterial bed (not, however, one at Barking or Crossness), especially rich in these "*acid-fast*" *bacteria*, did die from *tubercular* infection, and that sections of its organs when appropriately stained showed the presence of numerous *tubercle bacilli.*]

In view of these results, only one conclusion seems possible, namely, that however satisfactory the process may be from the chemical and practical point of view, *the effluents from the bacterial beds cannot be reasonably assumed to be more safe in their possible relation to disease than raw sewage slightly diluted, but otherwise unaltered in its bacterial composition.*

VII.—ADDENDA.

1.—THE VITALITY OF THE CHOLERA BACILLUS, B. PRODIGIOSUS, AND STAPHYLOCOCCUS PYOGENES AUREUS IN CROSSNESS CRUDE SEWAGE.

The sewage was not sterilised, as sterilisation greatly alters its chemical composition, and the object of the experiments was to ascertain broadly whether these germs survive for any length of time in competition with the numerous other micro-organisms normally present in raw sewage.

(*a*) Vitality of the Cholera Bacillus in Crossness Crude Sewage.

Experiment 1, *October* 24*th*, 1898.

10 c.c. of Crossness crude sewage were poured into a sterile test-tube, and the tube was plugged with sterile wool. The contents of the tube were next inoculated with a platinum loopful of the cholera bacillus taken from a young gelatine culture. The tube containing the crude sewage (+ the cholera bacillus) was kept in a dark cupboard at the room temperature. In seeking to determine the viability of Koch's vibrio the following plan was adopted. From time to time a loopful of the sewage was transferred to a tube containing sterile peptone solution (peptone 1 per cent.; NaCl 0·5 per cent.). The peptone tube was incubated at 37° C., and in less than twenty-four hours a loopful of the liquid was taken from near the surface and microscopic stained cover-glass preparations were made. A number of such preparations were made, and these were examined microscopically for the presence of Koch's vibrio.

The results obtained are shown in the following Table—

Date of inoculation of peptone solution.	Date of examination of peptone culture.	Descriptive number of cultures.	Remarks. Results of the examination of the peptone cultures.
1898.	1898.		
October 24 ... ... (Immediately after the inoculation of the sewage with Koch's vibrio.)	October 25	(1)	Cholera vibrios present in great abundance and almost in pure culture.
October 25	,, 26	(2)	Vibrios could only be found after prolonged searching.
,, 26	,, 27	(3)	No difficulty was experienced in finding vibrios.
,, 27	,, 28	(4)	Vibrios present in abundance.
,, 28	,, 29	(5)	A positive result was with difficulty obtained.
,, 31	November 1	(6)	,, ,,
November 1	,, 2	(7)	,, ,,
,, 2	,, 3	(8)	,, ,,
,, 3	,, 4	(9)	,, ,,
,, 4	,, 5	(10)	A doubtfully positive result.
,, 9	,, 10	(11)	Only a few vibrios, but these were typical.
,, 18	,, 19	(12)	Many vibrios, but most of them larger (longer and thicker) than normal.
,, 24	,, 25	(13)	? Positive.
December 5	December 6	(14)	Quite negative.

It is to be noted that in culture (1) Koch's vibrio was present almost in pure culture, but in (2) it was demonstrated only with great difficulty. In (3) and (4), however, vibrios were present in abundance. In (5), (6), (7), (8), (9) cultures a positive result was arrived at only with great difficulty, and in (10) the result was only doubtfully positive. In (11) and (12) cultures the diagnosis was more certain, but in the latter culture the microbe seemed to have become slightly altered, morphologically. In (13) there was a considerable element of doubt, and in (14) the result was quite negative.

The apparent rise and fall in the vitality of the vibrio during the progress of the experiment is of interest.

It is evident that the cholera bacillus is able to exist in Crossness crude sewage in competition with the numerous other microbes also present and under laboratory conditions of experiment for a considerable time.

Experiment 2, *October* 26*th*, 1898.

The experiment was a repetition of experiment 1, except that a vastly greater number of cholera germs were added to the sewage, viz., the whole of the surface growth from an oblique agar culture incubated at 37° C. for three days. Indeed, the number of vibrios added was greatly in excess of the total number of micro-organisms in the sewage.

The results obtained were as follows—

Date of inoculation of peptone solution.	Date of examination of peptone culture.	Descriptive number of cultures.	Remarks. Results of the examination of the peptone cultures.
1898.	1898.		
October 26 ... ... (Immediately after the inoculation of the sewage with Koch's vibrio.)	October 27	(1)	Cholera vibrios present in great abundance.
October 27	" 28	(2)	A positive result was obtained only with difficulty.
" 28	" 29	(3)	Vibrios found without difficulty.
" 31	November 1	(4)	" "
November 1	" 2	(5)	Only a few vibrios could be found.
" 2	" 3	(6)	A positive result was obtained without much difficulty.
" 3	" 4	(7)	Vibrios found without any difficulty.
" 4	" 5	(8)	A positive result was obtained but only after prolonged searching.
" 9	" 10	(9)	The result was negative.
" 18	" 19	(10)	" "
" 24	" 25	(11)	" "
December 5	December 6	(12)	" "

In this experiment, as in experiment 1, there was a difficulty experienced in finding the cholera bacillus in the peptone culture number (2) made only the day after inoculation. Yet in both experiments no difficulty was experienced in arriving at a positive diagnosis as regards number (3) peptone culture. Notwithstanding the enormous number of vibrios added to the sewage, they appeared to die out much sooner than in the preceding experiment.

Speaking in general terms, and dealing with both experiments, it may be said that under the above conditions of experiment the cholera bacillus may lose its vitality in less than a fortnight (experiment 2) or remain viable for nearly four weeks (experiment 1) when added to Crossness crude sewage.

(b) Vitality of B. Prodigiosus in Crossness Crude Sewage.

Experiment 3, *October 24th,* 1898.

In this experiment 10 c.c. of Crossness crude sewage were inoculated with *B. prodigiosus* (platinum loopful from a young agar culture). Although this micro-organism is occasionally met with in sewage it is very rare in London raw sewage, and so is to be regarded as being in a sense an intruder. The tube containing the raw sewage (+ *B. prodigiosus*) was kept in a dark cupboard at the room temperature.

In seeking to determine the viability of this microbe in the sewage the following plan was adopted—From time to time a loopful of the sewage (+ *B. prodigiosus*) was taken and rubbed over the sloping surface of oblique agar tubes. These were kept at the room temperature, and the presence of *B. prodigiosus* was readily detected by the bright red colour produced by the growth of this microbe in agar cultivations.

The results obtained are shown in the following Table—

Date of inoculation of the oblique agar tubes.	Descriptive number of cultures.	Results. As regards red growth on oblique agar tubes.
1898.		
October 24 ... ... (Immediately after the inoculation of the sewage with *B. prodigiosus*).	(1)	Positive.
October 25	(2)	"
" 26	(3)	"
" 27	(4)	"
" 28	(5)	"
" 29	(6)	"
" 31	(7)	"
November 1	(8)	" (only a few colonies).
" 2	(9)	" "
" 3	(10)	" "
" 4	(11)	" "
" 5	(12)	" (only 3 colonies).
" 7	(13)	" (only 1 colony).
" 9	(14)	" "
" 12	(15)	Negative.
" 14	(16)	"
" 16	(17)	"
" 18	(18)	"
" 25	(19)	"
December 3	(20)	"

It is to be noted that *B. prodigiosus* retained its vitality in the crude sewage for sixteen days. Afterwards it could not be found in any of the cultures. During the sixteen days *B. prodigiosus* remained alive it was noted that whereas at the start an abundant red growth showed itself in the agar cultures towards the end of this period the number of red colonies developing was very small, and in cultures (12), (13), and (14) the number of red growths was only three, one, and one respectively. Speaking in general terms it may be said that the number of *B. prodigiosus* decreased rather rapidly, and usually each successive culture showed less red growth than the one immediately preceding it.

Experiment 4, *November 2nd*, 1898.

This experiment was a repetition of experiment 3, 10 c.c. of Crossness crude sewage being inoculated with a platinum loopful of a recent growth of *B. prodigiosus* on agar.

The results obtained are shown in the following table—

Date of inoculation of the oblique agar tubes.	Descriptive number of cultures.	Results. As regards red growth on oblique agar tubes.
1898.		
November 2 ... ... (Immediately after the inoculation of the sewage with *B. prodigiosus*.)	(1)	Positive.
November 3	(2)	,,
,, 7	(3)	,,
,, 9	(4)	,, (only one colony).
,, 12	(5)	,, ,,
,, 14	(6)	Negative.
,, 16	(7)	,,
,, 18	(8)	,,
,, 24	(9)	,,
December 3	(10)	,,

In this experiment the *B. prodigiosus* remained alive for 10 days, but was not discoverable on the 12th, 14th, 16th, 22nd, or 31st day after inoculation.

Speaking of both the experiments it may be said that *B. prodigiosus* either dies or becomes so reduced in numbers as to be no longer capable of being isolated in from about 10 to 16 days in Crossness crude sewage under the above laboratory conditions of experiment.

It would seem from these experiments as if the cholera bacillus was capable of existing in sewage for a longer time than the *B. prodigiosus*. Assuming, of course, that the two different methods used for detecting these microbes were of equal delicacy, which is probably not quite the case.

(*c*) Vitality of Staphylococcus Pyogenes Aureus in Crossness Crude Sewage.

Experiment 5, *November 9th*, 1898.

In this experiment 10 c.c. of Crossness crude sewage were inoculated with a platinum loopful of a young agar culture of *staphylococcus pyogenes aureus*. This pathogenic microbe has been described as being occasionally present in raw sewage. My own experience leads me to believe that it is only very rarely present in sewage. Certainly it is to be regarded as a microbe foreign to the bacterial flora of ordinary sewage.

The tube containing the raw sewage (+ *St. pyogenes aureus*) was kept in a dark cupboard at the room temperature.

In seeking to determine the viability of this micro-organism in the sewage the following plan was adopted. From time to time a loopful of the sewage (+ *St. pyogenes aureus*) was taken and rubbed over the sloping surface of oblique agar tubes. These were incubated at 37° C., and the presence of *St. pyogenes aureus* was readily ascertained by the golden orange-yellow colour produced by the growth of this germ in agar cultures.

The results obtained are shown in the following Table—

Date of inoculation of the oblique agar tubes.	Descriptive number of cultures.	Results. As regards presence or absence of characteristic coloured growth of *St. pyogenes aureus*.
1898.		
November 9 ... ... (Immediately after the inoculation of the sewage with *St. pyogenes aureus*.)	(1)	Positive (decided growth)
November 10	(2)	,, ,,
,, 11	(3)	,, ,,
,, 12	(4)	,, ,,
,, 14	(5)	,, ,,
,, 17	(6)	,, ,,
,, 24	(7)	,, ,,
December 3	(8)	,, ,,
,, 14	(9)	Negative.
,, 17	(10)	Positive (one colony).

In cultures made subsequent to December 17th, no colonies of *St. pyogenes aureus* could be found.

It is to be noted that up to the twenty-fourth day after the original inoculation the presence of *St. pyogenes aureus* was easily demonstrated. But a negative result was obtained in the case of culture (9)—thirty-fifth day. Nevertheless, in culture (10) a single colony was discovered, *i.e.*, on the thirty-eighth day subsequent to inoculation. Later, the microbe was no longer discoverable in cultures made from the sewage.

From this experiment it would seem that *St. pyogenes aureus* is capable of retaining its vitality in Crossness crude sewage for a considerable time.

In conclusion, and speaking in general terms of all the experiments, it may be stated that the cholera bacillus (pathogenic), *B. prodigiosus* (non-pathogenic), and *St. Pyogenes aureus* (pathogenic) are capable of retaining their vitality in Crossness crude sewage in competition with the very numerous bacteria normally present in the liquid for a considerable time. But it must be insisted upon that the conditions prevailing in laboratory test-tube experiments are widely different from those in operation in biological coke-beds. Nevertheless, and looking at the subject from the point of the epidemiologist, these experiments are far from reassuring, and, indeed, would seem to indicate that the antagonism of the saprophytic bacteria normally present in sewage would not suffice for the destruction of pathogenic species either in the sewers or, later, in the bacterial beds. Since the bacterial beds are purposely constructed so as not to mechanically hold back the suspended matters, and as it is to be feared from these experiments that the biological processes at work in the coke-beds would not rapidly destroy the life, although they might inhibit the multiplication of pathogenic germs accidentally introduced into the crude sewage, the effluents from the beds ought to be regarded as no more safe in their possible relationship to disease than the raw sewage itself. It must be remembered, however, that the number of the pathogenic germs added to the sewage in these experiments was vastly greater than could conceivably take place under natural conditions, and that, notwithstanding the enormous number introduced, there was definite indication of a somewhat rapid decrease in their numbers.

For records relating to the passage through the bacterial beds of pathogenic germs habitually or occasionally present in crude sewage reference must be made to other sections of this Report and also to previous Reports.

2.—THE INOCULATION OF THE 13-FOOT COKE-BED AT CROSSNESS WITH A SPECIAL SEWAGE MICROBE.

Most observers who have had any practical experience of the so-called biological treatment of sewage are agreed as to the necessity of treating *new* bacterial beds with small but gradually increasing doses of raw sewage until they have become thoroughly *matured*. Further, it is generally believed that a *mature* bed is one which has become by a natural process of selection *charged* with the special bacteria concerned in the work of purification. By varying the conditions in a number of ways changes, favourable or the reverse, may readily be induced. For example, by overtaxing the coke-beds a change commonly spoken of as "*sickening*" may set in when the chemical results will no longer be satisfactory. In such a case it may be conjectured that the wrong kind of bacteria have gained the ascendancy. Conversely, by greatly diminishing the amount of sewage to be "*treated*," a particularly good effluent may often be obtained. Here presumably the special bacteria are able to multiply abundantly and to exercise their specific qualities to the best advantage. Exactly which kind of bacteria are directly beneficial and which act as intruders is not yet clearly known, although the broad fact that putrefactive and nitrifying germs are necessary has long been established. Nor is it properly understood under what conditions the special bacteria should be placed in order to allow them to exercise their beneficial qualities to the best advantage. Bacterial processes so widely different as those which aim at encouraging the growth of aërobic micro-organisms and those which are essentially or largely anaërobic in character, have been put in operation by different workers. And each observer claims for his own process peculiar advantages. But it will be gathered from what has been said that probably all the bacterial processes in practical operation at the present time aim at allowing certain bacteria or groups of bacteria to gain the ascendancy by a *natural process of selection*.

Although this is certainly a rational method of "*treating*" sewage it is to be thought of that the future of the biological treatment of sewage may possibly lie in the direction of a real or apparent interference with nature's methods. In the absence of absolute knowledge as to the exact conditions under which sewage should be placed so as either in one or a succession of stages to foster the growth of the bacteria directly concerned in the work of purification and to inhibit the growth of unnecessary or harmful germs it is conceivable that the addition (continuously or intermittently) of pure cultures in large amount of selected microbes might exercise a beneficial effect. Which kinds of bacteria should be added, and under what conditions, cannot safely be affirmed in the present state of our knowledge. The experiments might be conducted so as to aid or abet nature rather than with the object of interfering with or upsetting the natural order of things, and they might occupy several stages. Further, they might be carried out in connection with bacterial beds already for some time in operation or new beds might be sown with special bacteria previous and preparatory to the application of sewage. It is conceivable that they might be divided into two stages—the first aërobic or semi-anaërobic, the bacteria used belonging to the class of putrefactive aërobes and facultative anaërobes, and the second stage purely aërobic, the micro-organisms involved in the process being those of nitrification, or, preliminary to the above, and as an initial stage anaërobic bacteria might be employed. Lastly, the experiments might be conducted from the epidemiological point of view rather than with the sole idea of obtaining an effluent chemically sound. For as it is known that certain micro-organisms are antagonistic to others, the special bacteria selected might be saprophytes, the products of whose growth act as bactericidal agents to pathogenic germs.

Of course it will be argued that nature's own methods are the best, and that any interferance with the natural course of events is not to be recommended, and that it would be wise to first determine more accurately the precise functions of the different bacteria concerned in the work of

the purification of sewage before proceeding to add special bacteria to a liquid or to a bacterial bed already harbouring all the known microbes of putrefaction and nitrification.

Such contentions are certainly justifiable, but it is to be thought of that the path to knowledge does not always lie along the most direct route, and accident has before now revealed the truth where experiments conducted on apparently sound lines have entirely failed.

Although, as regards the so-called biological treatment of sewage, the results obtained in the past have been most encouraging, at all events, from the chemical point of view, it is now clearly established that all the different processes which have been tried, suffer from serious limitations which at the present time seem almost insuperable in character.

It is conceivable that both from the practical and epidemiological point of view a solution of the problem of sewage disposal may lie in one or other of the directions that has been indicated.

The stress of work involved in the periodical examination of the crude sewage and effluents from the coke-beds made it impossible to carry out any prolonged research of the above nature.

Neverthel ss, one experiment was tried, and although attended with apparently negative results, its description will not be out of place.

It will be remembered that in previous Reports it was shown that a rapidly-liquefying gas-forming proteus-like germ was present in London crude sewage in numbers usually exceeding 100,000 per c.c. This microbe was also found to be present in the effluents in very large numbers. Its ability to form gas, its rapid peptonising action and its abundance seemed to indicate that it was possibly a microbe specially concerned in the work of purification. Accordingly it was determined to isolate a strain of this micro-organism from an effluent, to cultivate it on a large scale, and to add it in great amount to the crude sewage during the ordinary process of filling a matured coke-bed.

Three strains of "*sewage proteus*"* were isolated from $\frac{1}{10000}$ c.c. of Barking primary B effluent, (December 6th, 1899). They all grew luxuriantly at blood-heat, formed gas in twenty-four hours in gelatine shake cultures, liquefied gelatine very rapidly, and were very motile. One proved virulent when injected into a guinea-pig; another produced a strong local reaction, but the animal recovered, while the third was apparently non-pathogenic. The latter microbe was used in the experiment.

700 c.c. of agar were added to about 70 tubes and sterilised. The agar was allowed to solidify obliquely in the test tubes. The tubes were next inoculated with the "sewage proteus" and incubated at 20° C.

The growth from each of the tubes was transferred to sterile bouillon (1,500 c.c.), and the mixture of bacteria and broth used to inoculate the crude sewage as it flowed on to the 13-foot coke-bed at Crossness. This meant the addition of billions of *B. proteus* to the sewage.

The experiment was carried out in the following way—

On December 19th, 1899, the bacterial mixture (1,500 c.c.) was added to the crude sewage (about 6,000 gallons) as it flowed on to the coke-beds, the addition being made in small quantities at a time, so as to cover the whole of the period occupied in filling the bed, namely, about twenty minutes.

The bed was allowed to remain full for the usual period, namely, three hours, and it was emptied in the usual manner.

During the process of emptying, and especially during the first flow of the effluent, a number of vessels in bulk representing approximately thirty gallons—were filled with the effluent and kept in a warm place.

When the time arrived for filling the coke-bed again the contents of the vessels were added to the sewage flowing on to the bed.

Further, when, after the usual period, the bed was again emptied, the vessels were again filled with the first flow of the effluent.

The above series of operations was carried out until December 22nd, i.e., the crude sewage (about 6,000 gallons) as it flowed on to the coke-bed was first charged on December 19th with a mixture of *B. proteus* and broth (1,500 c.c.) (the microbes being present in number inconceivably great), and subsequently on six other consecutive occasions with the first flow of the effluent from the previous emptying of the coke-bed.

Most unfortunately at this period circumstances arose which made it impossible to test the value of the experiment from the biological point of view. This is greatly to be regretted, as it would have been of interest to have known if *B. proteus* was more numerous in the effluent than normally, and, if so, how long such numerical superiority was maintained. Further, whether its presence exercised any inhibiting influence on any of the other bacteria usually found in the crude sewage and effluents.

Mr. Biggs, the chemist in charge at the Southern Outfall Works, kept careful notes during the above period. He was unable either from the chemical or practical point of view to arrive at any other conclusion than that the experiment yielded quite negative results. That is to say the inoculation of the coke-bed with *B. proteus* did not produce any appreciable alteration in the effluent either as regards its chemical composition or physical appearance. Nor was the capacity of the coke-bed increased. The negative results may have been more apparent than real. Possibly if the effluents had been tested bacteriologically well defined changes might have been observed in the bacterial composition of the liquid extending over a longer or shorter period. It is conceivable also that if *B. proteus* had been added in still greater amount and for a longer period totally different results might have been obtained. To overcome the biological equilibrium of a *mature* coke-bed of the large capacity of the 13-foot bed at Crossness would naturally call for the addition of an enormous number of micro-organisms.

In conclusion, it must be insisted upon that the apparently negative character of this single experiment in no way suggests the advisability of abandoning a research carried out on the lines that have been here briefly indicated.

* The morphological and biological characters of "*sewage proteus*" have been already described. See Second Report, V. 3, page 36.

3.—THE EFFECT, AS REGARDS THE RESULTANT QUALITY OF THE EFFLUENTS FROM THE BACTERIAL BEDS, OF THE ADDITION OF CERTAIN CHEMICAL SUBSTANCES TO THE BARKING CRUDE SEWAGE.

It is known that some species of micro-organisms act with great vigour in the presence of a large excess of certain basic substances. For example, the nitrifying germs show increased bacterial activity when grown in liquid media containing an excess of magnesium or calcium carbonate. It is supposed that the solid grains besides neutralising the products of bacterial activity, act as what may be termed "contact points," enabling the bacteria to localise and concentrate themselves at a multitude of different spots. Further, if the liquid is in motion the grains may act as "carriers" of the microbes and their products from one place to another.

It is a matter of controversy among those who have practical concern with bacterial beds which is the best material to use. Some assert that the actual chemical composition of the substance is of no importance, that it is the physical qualities (e.g., whether smooth or jagged, pervious or impervious) of the material which is all essential. Others believe that certain substances are preferable to all others in virtue of their ability of exerting a basic action on the products of bacterial growth and of encouraging the active growth of special micro-organisms. However this may be, it is of interest to note that Mr. E. Brooke Pike, the chemist in charge at Barking, suggested the trial of ragstone as a better material in respect of its chemical composition than coke. This was agreed to by Dr. Clowes, and accordingly a trial was made of the comparative values of ragstone and coke bacterial beds. The outcome of these experiments seemed to be that the ragstone coke-beds did encourage the growth of the nitrifying germs (as evidenced by an increased production of oxidised nitrogen), but that the effluents, as regards the removal of dissolved oxidisable and putrescible matter, were not so satisfactory from the ragstone as from the coke-beds.

Although it is quite conceivable that the actual chemical composition of the material in a bacterial bed, quite apart from its physical characters, may play a definite part in influencing the biological processes at work in the bed, it is evident that the action, whatever it may be, cannot be expected to persist for an indefinite period.

With this idea in view, I suggested the trial of the artificial addition, in small amounts, of some such substance as magnesium carbonate or calcium carbonate to the sewage as it flowed on to the beds, as likely to produce a beneficial effect by its diffusion throughout the liquid in the beds and also by its settling on the surface of the fragments of coke and effecting a lodgement there. It was hoped that not only would the result be immediately beneficial, but that the good effect would be maintained for a considerable period after the addition of the substance had been abandoned. In short, that it would only be necessary to occasionally and very rarely resort to such an artificial measure in order to obtain uniformly good results. With Dr. Clowes' permission Mr. E. Brooke Pike was good enough to carry out some very careful experiments in this direction.

In the first series of experiments he added magnesium carbonate emulsion to the crude sewage as it flowed on to the beds in such strength as to correspond to 0·001 part of magnesium carbonate to every 100 parts of raw sewage.* This was done each time the beds were filled, viz., twice a day between Wednesday, 21st March, and Wednesday, March 28th, 1900, both days inclusive.

The results as regards oxidised nitrogen and oxygen absorbed from permanganate were as follows—

Oxygen absorbed from Permanganate in Four Hours at 80° F.

Parts per 100,000.

	Crude sewage.	Effluent from primary coarse bed; series A.	Effluent from secondary coarse bed; series A.	Effluent from primary coarse bed; series B.	Effluent from secondary fine bed; series B.
Average of determinations made on March 7, 8, 9, 10, 12, 13, 14, 16, 19, 20, 1900.					
Before the addition of magnesium carbonate	6·740	3·410	2·280	3·420	1·780
Purification	—	49·4 per cent.	66·2 per cent.	49·3 per cent.	73·6 per cent.
Average of determinations made on March 21, 22, 23, 24, 26, 27, 28, 1900.					
During the addition of magnesinm carbonate	7·343	3·460	2·429	3·343	1·886
Purification	—	52·9 per cent.	66·9 per cent.	54·5 per cent.	74·3 per cent.
Increase in purification	—	3·5 per cent.	0·7 per cent.	5·2 per cent.	0·7 per cent.
Nitrogen as Nitrates.					
Average of determinations made on March 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 19, 20, 1900.					
Before the addition of magnesium carbonate	—	·3726	1·2113	·3334	2·0238
Average of determinations made on March 21, 22, 23, 24, 26, 27, 28, 1900.					
During the addition of magnesium carbonate	—	·4469	1·1854	·4439	2·3935
Increase in amount of oxidised nitrogen	—	+19 per cent.	—2 per cent.	+33 per cent.	+18 per cent.

* This minimal quantity (·001 per cent.) was used as a preliminary, as it did not seem desirable to materially increase the suspended matters in the sewage.

It will be noted that all the beds showed a very slight but still an appreciable improvement as regards removal of dissolved oxidisable matter, presumably as the result of the magnesium carbonate treatment. Thus the increase in purification in the different effluents was 3·5 per cent.; 0·7 per cent.; 5·2 per cent.; 0·7 per cent.

The figures as regards oxidised nitrogen were more encouraging. Thus, with the exception of the secondary coarse bed (series A), where there was a decrease equal to 2 per cent., all the other effluents showed a definite increase of nitrates amounting to 19, 33, and 18 per cent. respectively as regards the effluents from the primary coarse bed (series A), the primary coarse bed (series B), and the secondary fine bed (series B).

In a sense there was a double gain as a result of the treatment, because the effluents contained a slightly smaller amount of putrescible matter and also carried with them into the river a greater amount of an oxidising substance.

But while the results are of considerable interest from the scientific point of view as affording some confirmation of theoretical considerations, it can hardly be said that they are of equal importance from the practical point of view. They do not, in short, indicate the advisability of continuing the addition of magnesium carbonate as a measure of *practical utility.*

In the second series of experiments Mr. E. Brooke Pike added, as well as magnesium carbonate, a like quantity (viz., ·001 per cent.) of sodium carbonate.

Without entering into detail, it may be said that the results were no longer satisfactory, and indeed showed a general decrease in respect of nitrate production and of removal of dissolved oxidisable matter. The amount of sodium carbonate added was presumably too small to inhibit bacterial growth, and it is difficult to explain the falling off in the results, unless it be assumed that the sodium carbonate actually increased the vital activity of the micro-organisms in general, but in particular of the de-nitrifying germs and those specially concerned in producing putrefactive changes.

In conclusion, it may be said that further and more prolonged experiments seem desirable with magnesium carbonate and calcium carbonate, as well as with other substances. These might be tried in varying amounts and added continuously or intermittently. The experiments, of course, which have been described were merely of a tentative character. They may serve, however, to indicate a line of inquiry, not devoid of scientific interest and possibly of practical importance, which has hitherto been neglected.

PLATE I.

Fig. 1. *Streptococcus X.*—Microscopic preparation from a broth culture. 24 hours' growth at 38° C. Stained by Gram's method. Isolated from $\frac{1}{1000}$ c.c. of effluent from the 6-foot secondary coke-bed at Crossness. X 1,000.

Fig. 2. *Streptococcus XIX.*—Microscopic preparation from a broth culture. 48 hours' growth at 38° C. Stained by Gram's method. Isolated from $\frac{1}{1000}$ c.c. of effluent from the primary coarse bed (Series A) at Barking. X 1,000.

Fig. 3. *Streptococcus XX.*—Microscopic preparation from a broth culture. 48 hours' growth at 38° C. Stained by Gram's method. Isolated from $\frac{1}{1000}$ c.c. of effluent from the secondary coarse bed (Series A) at Barking. X 1,000.

Fig. 4. *Streptococcus XXI.*—Microscopic preparation from a broth culture. 48 hours' growth at 38° C. Stained by Gram's method. Isolated from $\frac{1}{1000}$ c.c. of Barking crude sewage. X 1,000.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

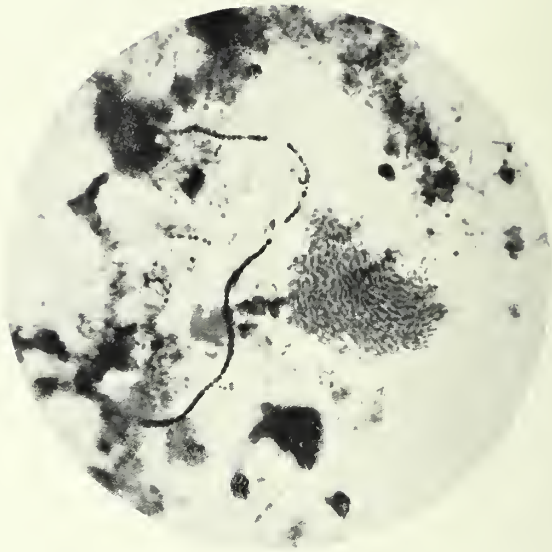


Fig. 6.

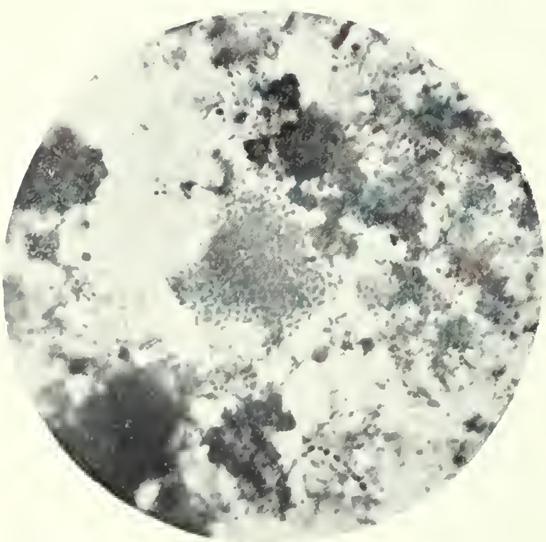


Fig. 7.

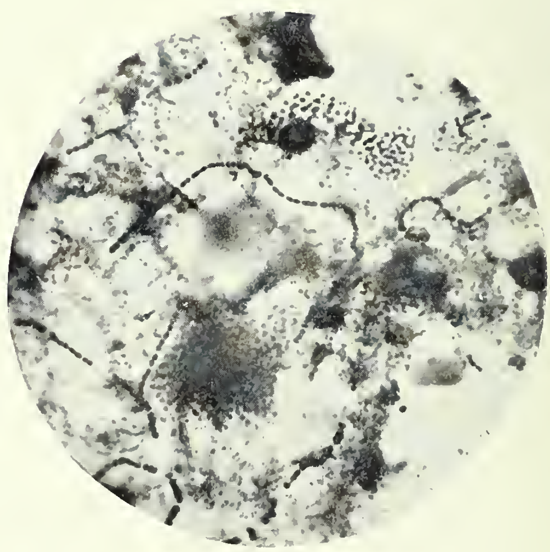


Fig. 8.

PLATE II.

FIG. 5. *B. Pyocaneus.*—MICROSCOPIC PREPARATION FROM AN AGAR CULTURE. 24 HOURS' GROWTH AT 38° C. ISOLATED FROM $\frac{1}{1000}$ C.C. OF THE EFFLUENT FROM THE SECONDARY COARSE BED (SERIES A) AT BARKING. X 1,000.

FIGS. 6, 7 AND 8. *Deposit Crossness crude sewage.*—50 C.C. OF THE RAW SEWAGE WERE CENTRIFUGALISED AND A MICROSCOPIC PREPARATION MADE OF THE DEPOSIT. THIS WAS WASHED IN ACID, THEN IN WATER, AND FINALLY STAINED WITH METHYLENE BLUE. IT SHOWS ZOOGLŒA-LIKE MASSES OF COCCI AND CHAINS OF COCCI (STREPTOCOCCI). [IN THE SUPPLEMENT TO THE SECOND REPORT IT WAS STATED (PAGE 5) THAT—"NUMEROUS PREPARATIONS SUBSEQUENTLY MADE SHOW THAT EITHER COCCI, OR RODS SO SHORT AND ROUNDED AT THEIR ENDS AS TO SIMULATE COCCI, PREDOMINATE IN MICROSCOPIC STAINED SPECIMENS MADE FROM SEWAGE AND EFFLUENTS, AND NOT, AS MIGHT HAVE BEEN IMAGINED, DISTINCT BACILLARY OR ROD-SHAPED FORMS."] X 1,000.

PLATE III.

Fig. 9. *B. Thermophilus* (or allied form).—Microscopic preparation from a broth culture. Isolated from Barking crude sewage. In illustration of one of the thermophilic bacteria—these microbes are abundant in the raw sewage and in the effluents from the coke-beds, and grow luxuriantly at a temperature of 60–70° C. X 1,000.

Fig. 10. Same as fig. 9. X 500.

Fig. 9.

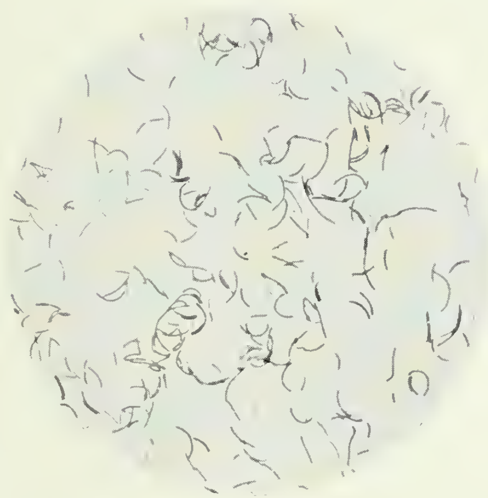


Fig. 10.

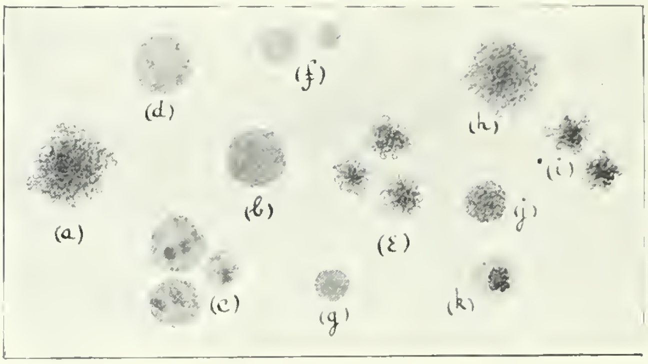


Fig. A.

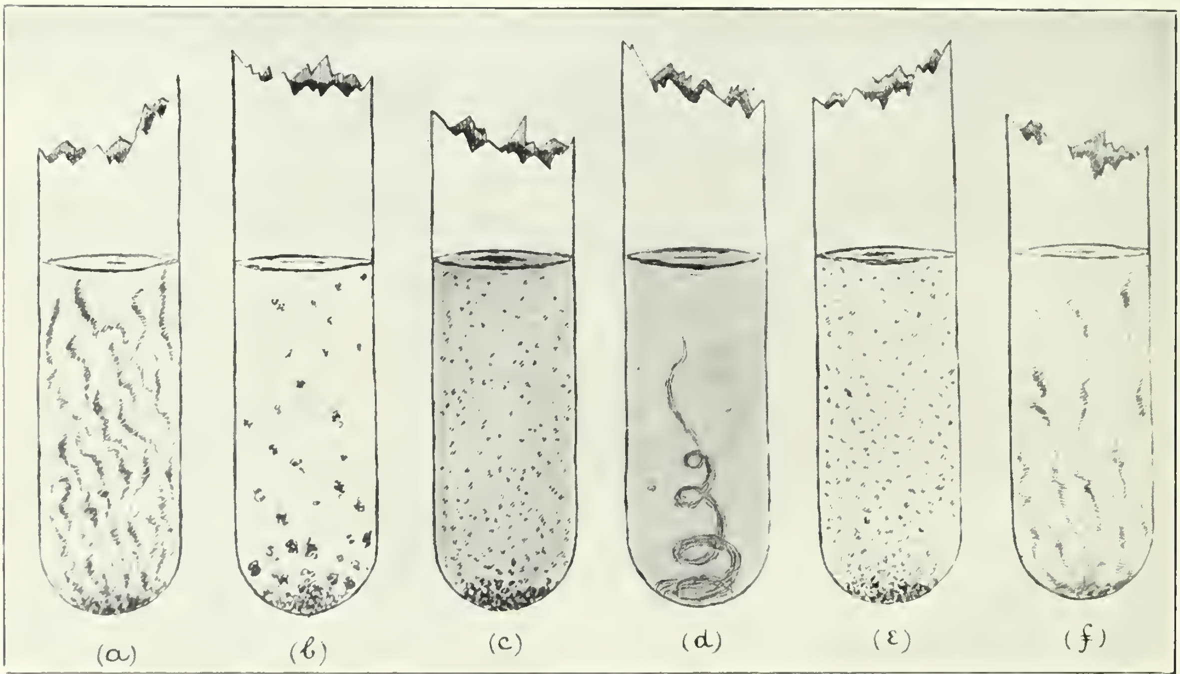


Fig. B.

PLATE IV.

Fig. A.

Colonies of Streptococci in gelatine and agar plate cultures.—Under a low power of the microscope (Leitz, 3 objective, 1 ocular.)

(Diagrammatic.)

(*a*)	Streptococcus	I.	Colony in agar plate.
(*b*)	,,	II.	Colony in agar plate.
(*c*)	,,	II.	Colonies in old gelatine culture.
(*d*)	,,	III.	Colony in agar plate.
(*e*)	,,	X.	Colonies in agar plate.
(*f*)	,,	XI.	Colonies in gelatine plate.
(*g*)	,,	XII.	Colony in gelatine plate.
(*h*)	,,	XIII.	Colony in agar plate.
(*i*)	,,	XIII.	Colonies in gelatine plate.
(*j*)	,,	XIV.	Colony in gelatine plate.
(*k*)	,,	XVIII.	Colony in gelatine plate.

Fig. B.

Broth and gelatine (incubated at blood heat) cultures of streptococci.

(Diagrammatic.)

(*a*)	Streptococcus	I.	Gelatine culture incubated at 37° C. for 2 days.
(*b*)	,,	I.	Old broth culture (shaken up).
(*c*)	,,	II.	Gelatine culture incubated at 37° C. for 2 days.
(*d*)	,,	II.	Broth culture (shaken).
(*e*)	,,	IV.	Gelatine culture, 24 hours at 37° C.
(*f*)	,,	XVII.	Broth culture, 2nd day at 37° C.

PLATE V.

Fig. C.

(Diagrammatic.)

Colonies (*superficial and deep*) of spore-forming anaërobes in agar plate cultures (previously inoculated with $\frac{1}{10}$ c.c. of crude sewage or of effluent and then heated to 80° C. for 10 minutes: Cultivated under anaërobic conditions at 37° C.). Under a low power of the microscope (Leitz, 3 objective, 1 ocular).

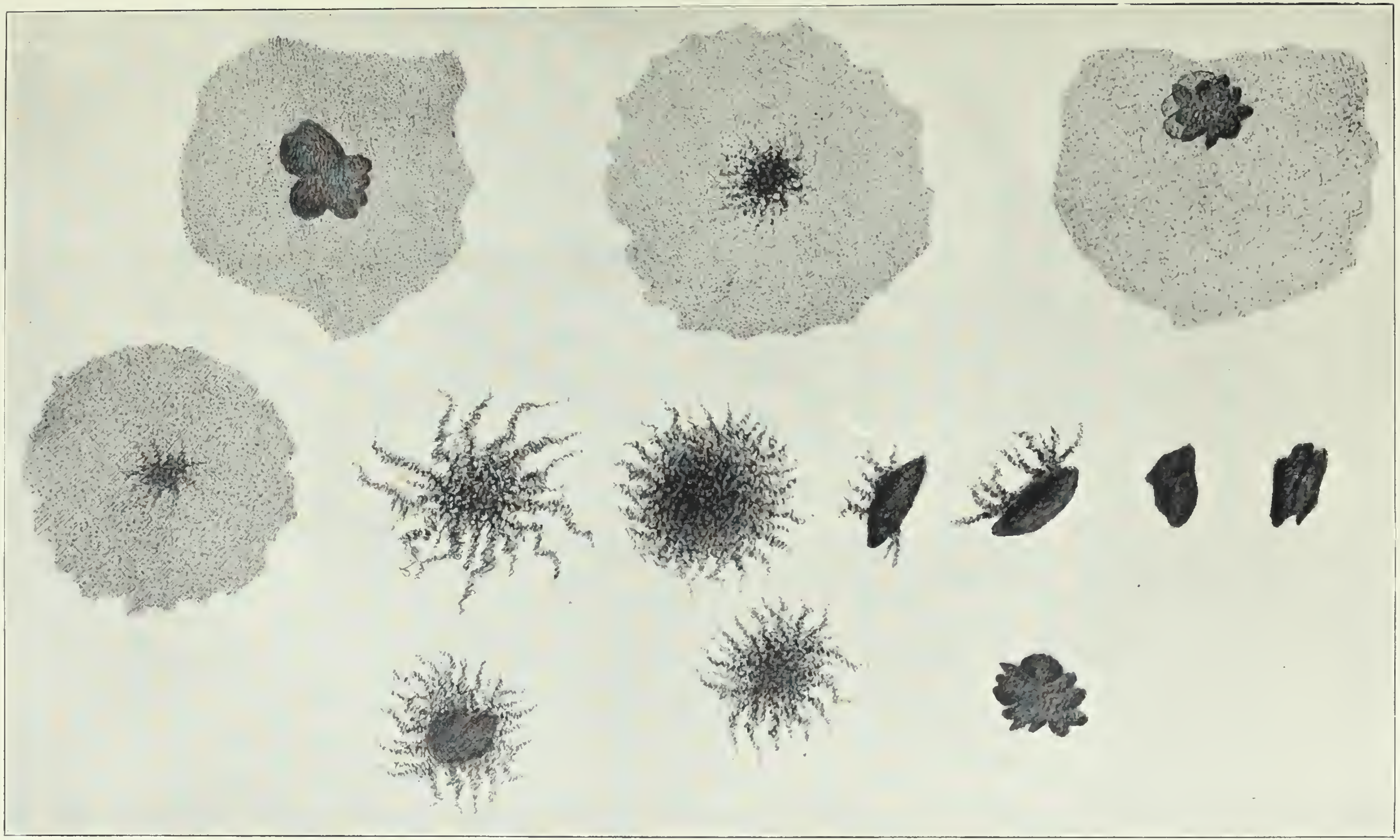
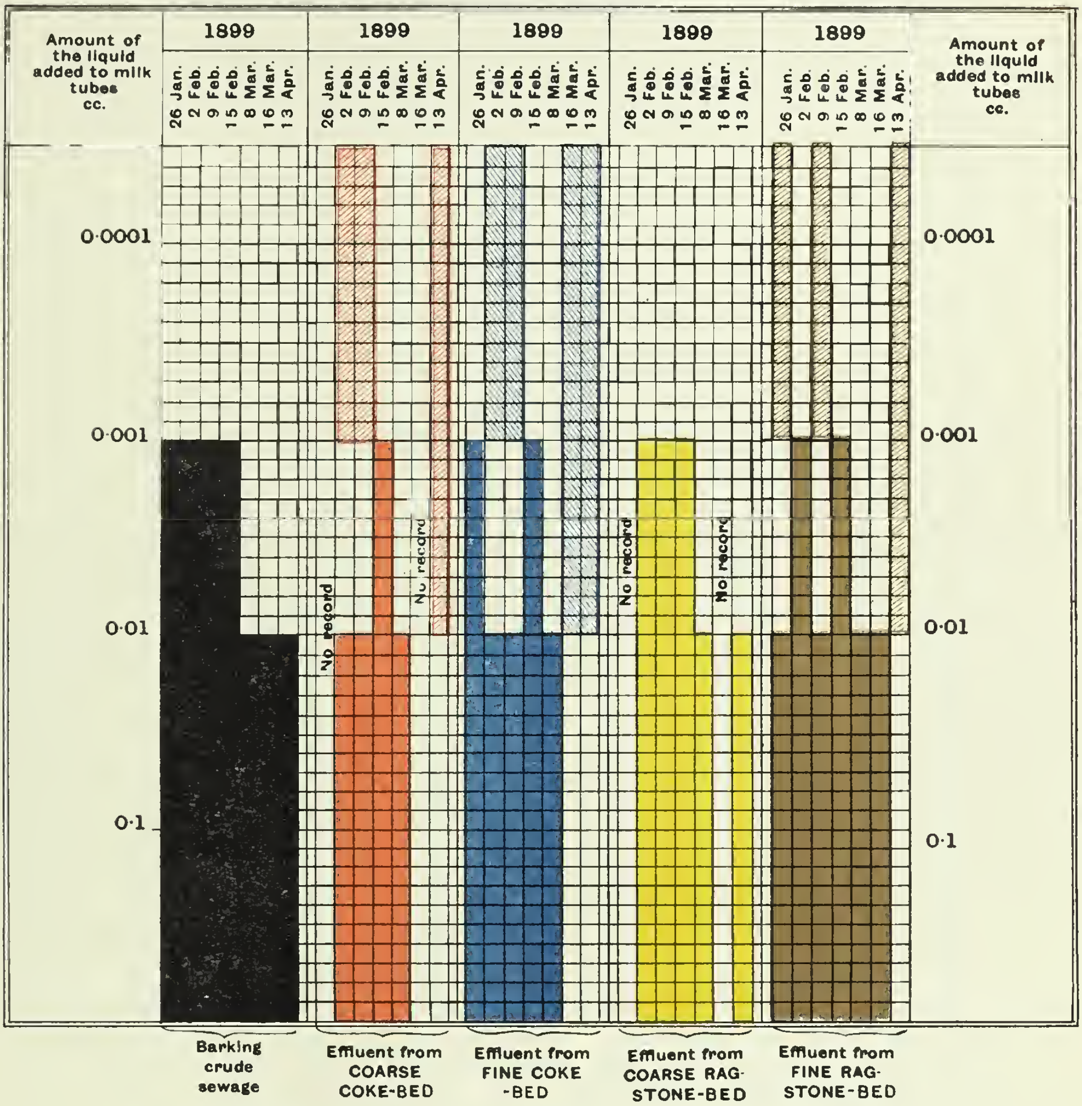


Fig. C.

DIAGRAM I.

Showing the number of spores of Bacillus Enteritidis Sporogenes in Barking crude sewage and in the effluents from the coarse and fine coke-beds, and also in the effluents from the coarse and fine ragstone-beds.



The "upward" columns refer to the SMALLEST amount of the liquid yielding a POSITIVE result as regards Bacillus Enteritidis Sporogenes when inoculated into milk tubes.

The "downward" columns refer to the LARGEST amount of the liquid yielding a NEGATIVE result as regards Bacillus Enteritidis Sporogenes when inoculated into milk tubes.

DIAGRAM 2.

Showing the total number of Bacteria in 1 cc of Barking crude sewage and in 1 cc of the effluents from the primary & secondary coarse beds (Series A); and the primary coarse bed and secondary fine bed (Series B).

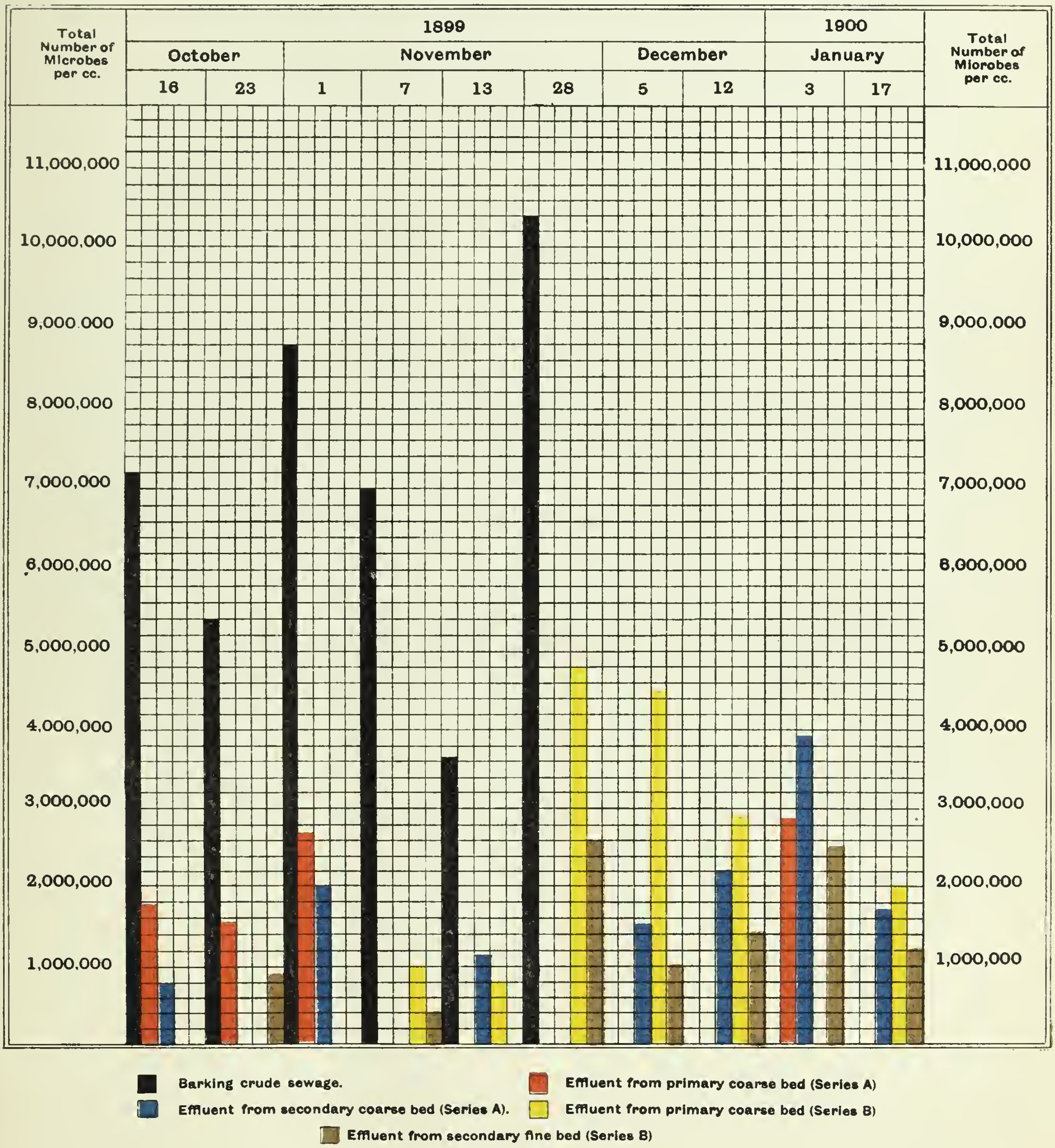


DIAGRAM 3.

Showing the number of Bacillus Coli (or closely allied forms) in 1 cc of Barking crude sewage, and in 1 cc. of the effluents from the primary and secondary coarse beds (Series A); and the primary coarse bed and secondary fine bed (Series B).

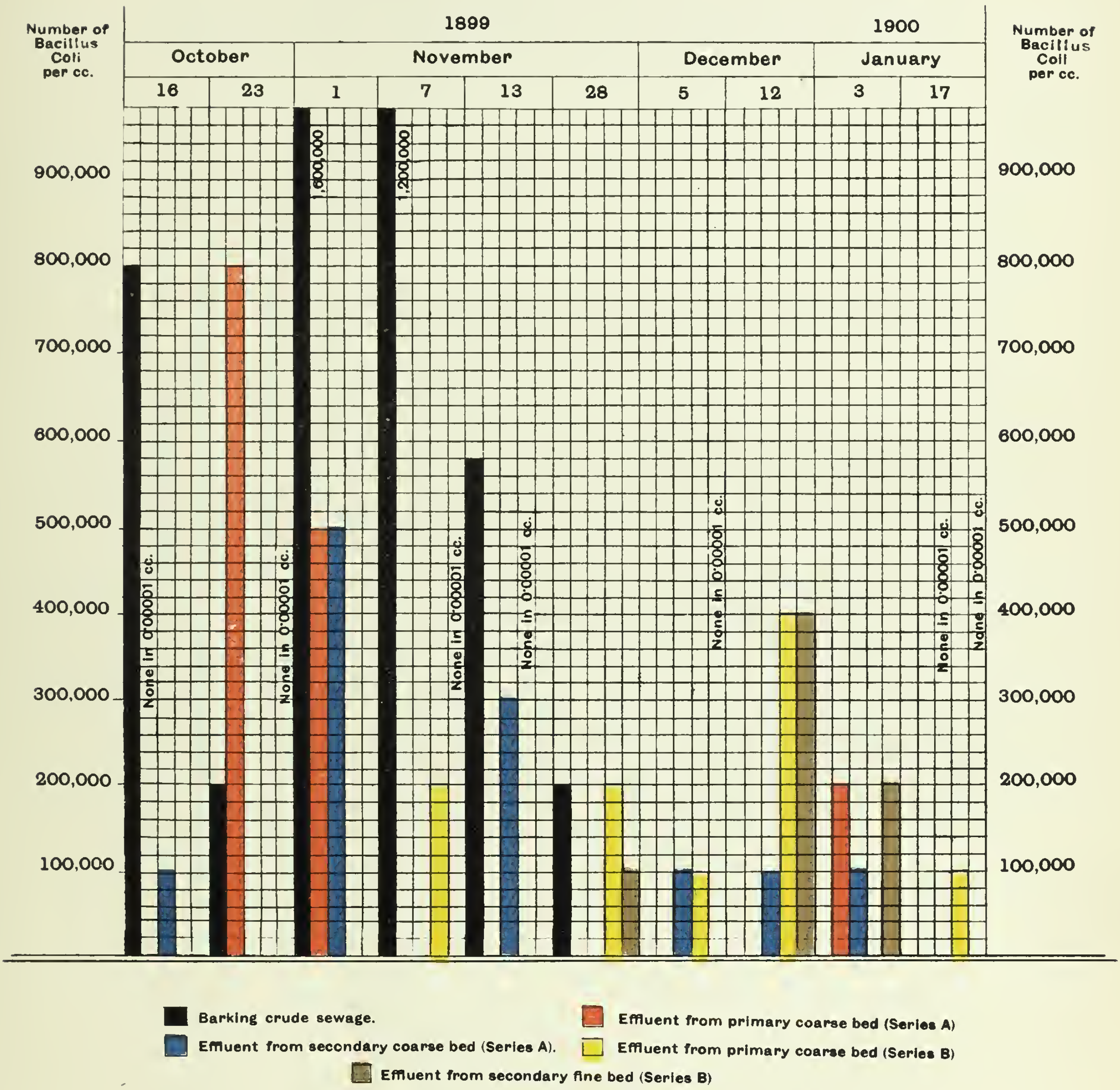
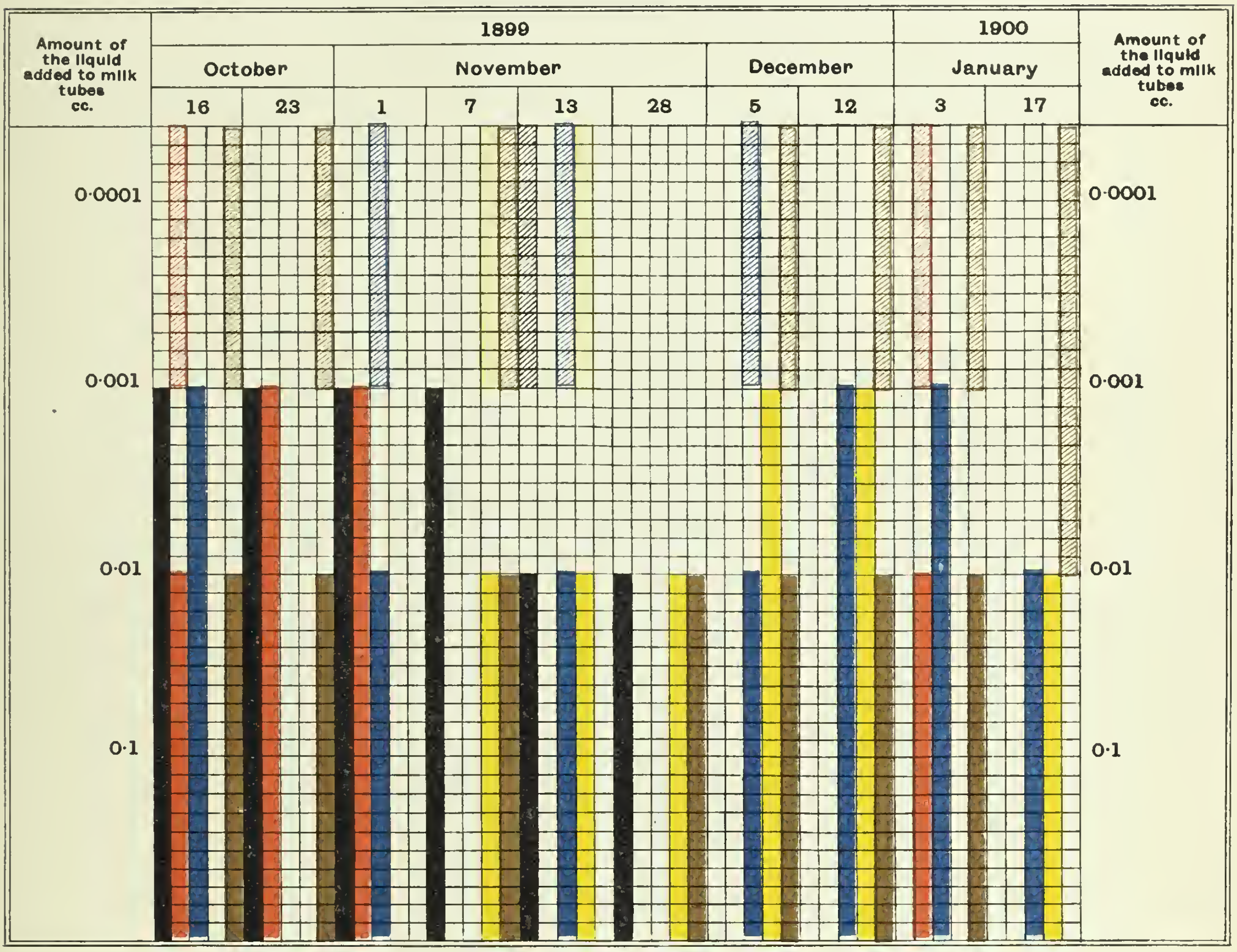


DIAGRAM 4.

Showing the number of spores of Bacillus Enteritidis Sporogenes in Barking crude sewage and in the effluents from the primary and secondary coarse beds (Series A); and the primary coarse bed and secondary fine bed (Series B).



Barking crude sewage.

Effluent from primary coarse bed (Series A)

Effluent from secondary coarse bed (Series A).

Effluent from primary coarse bed (Series B)

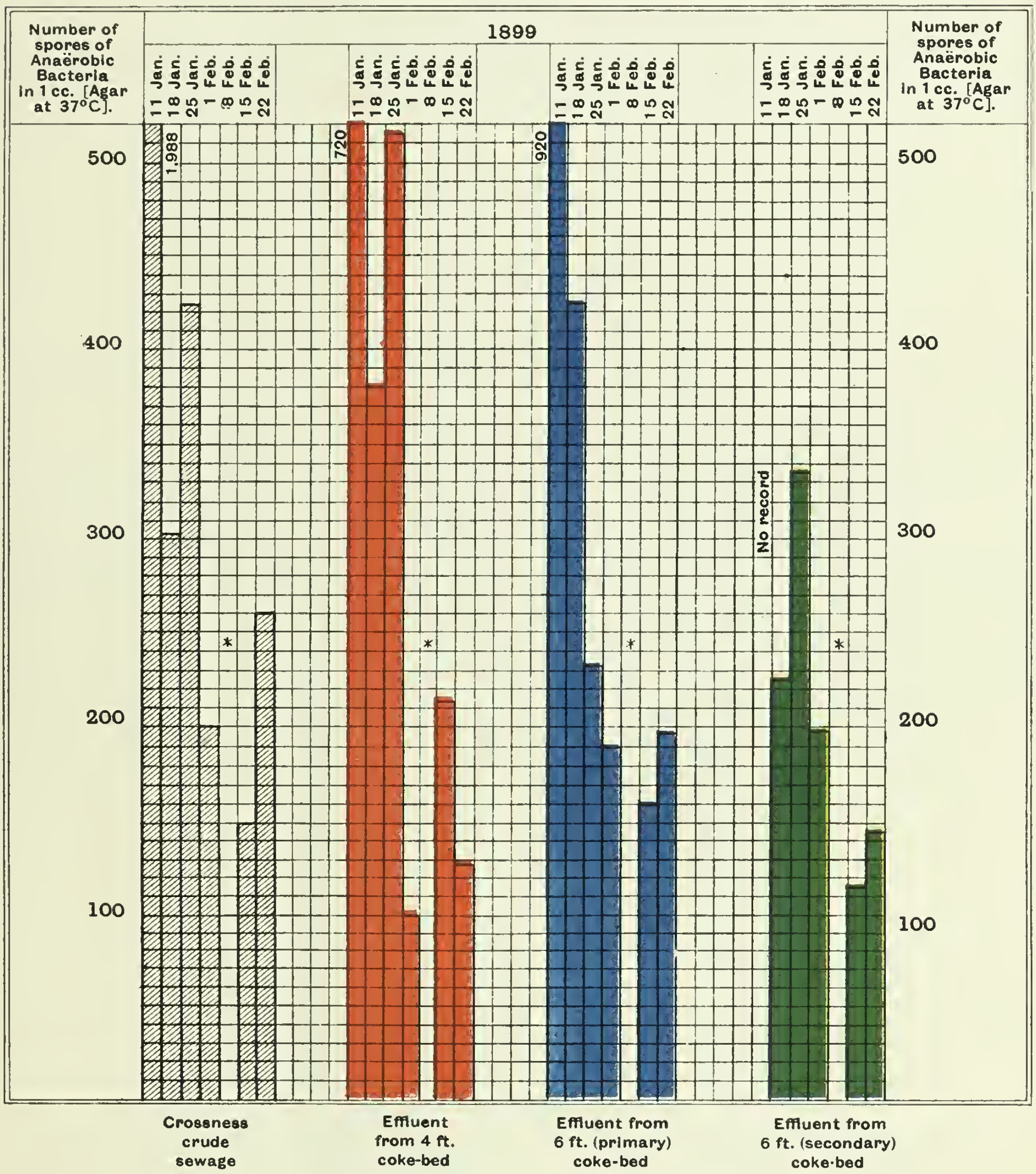
Effluent from secondary fine bed (Series B)

The "upward" columns refer to the SMALLEST amount of the liquid yielding a POSITIVE result as regards Bacillus Enteritidis Sporogenes when inoculated into milk tubes.

The "downward" columns refer to the LARGEST amount of the liquid yielding a NEGATIVE result when inoculated into milk tubes.

DIAGRAM 5.

Showing the number of spores of Anaërobic Bacteria in 1 cc. of Crossness crude sewage and in 1 cc. of the effluent from the 4 ft., 6 ft. (primary), and 6 ft. (secondary) coke-beds. [Agar at 37° C].



* The growths spread over the surface of the medium preventing accurate counting.

DIAGRAM 6.

Showing the total number of Bacteria in 1 cc. of Crossness crude sewage, and in 1 cc. of the effluent from the 13 ft. coke-bed.

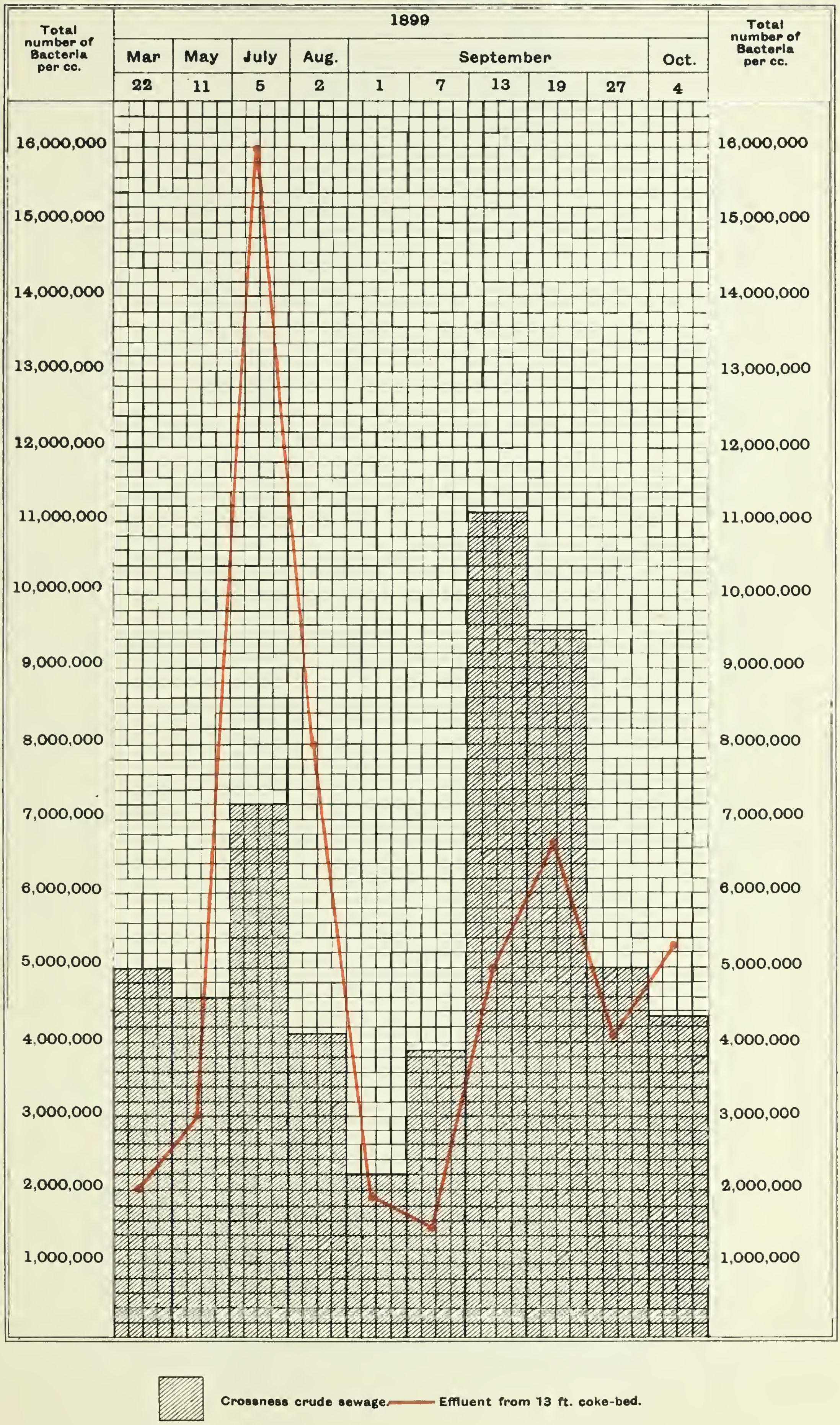


DIAGRAM 7.

Showing the number of Bacillus Coli (or closely allied forms) in 1 cc. of Crossness crude sewage, and in 1 cc. of the effluent from the 13 ft. coke-bed.

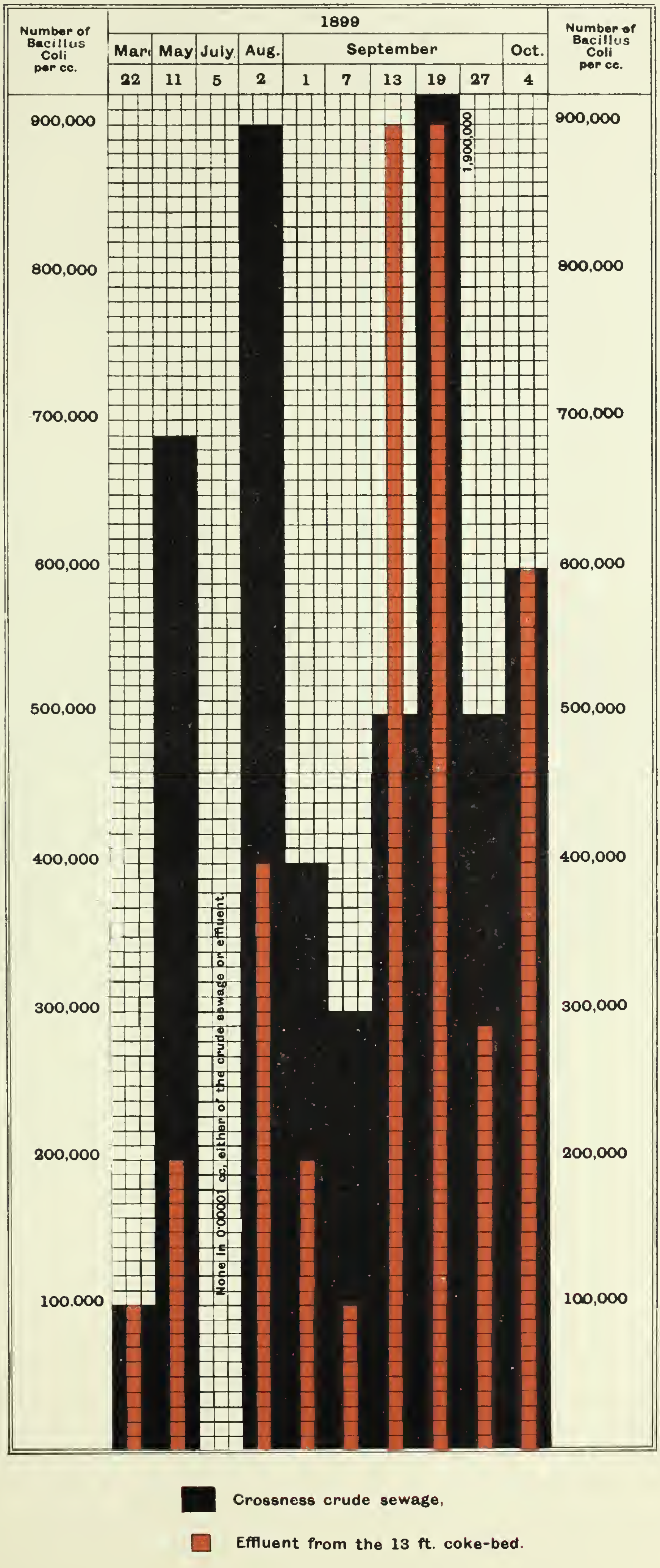
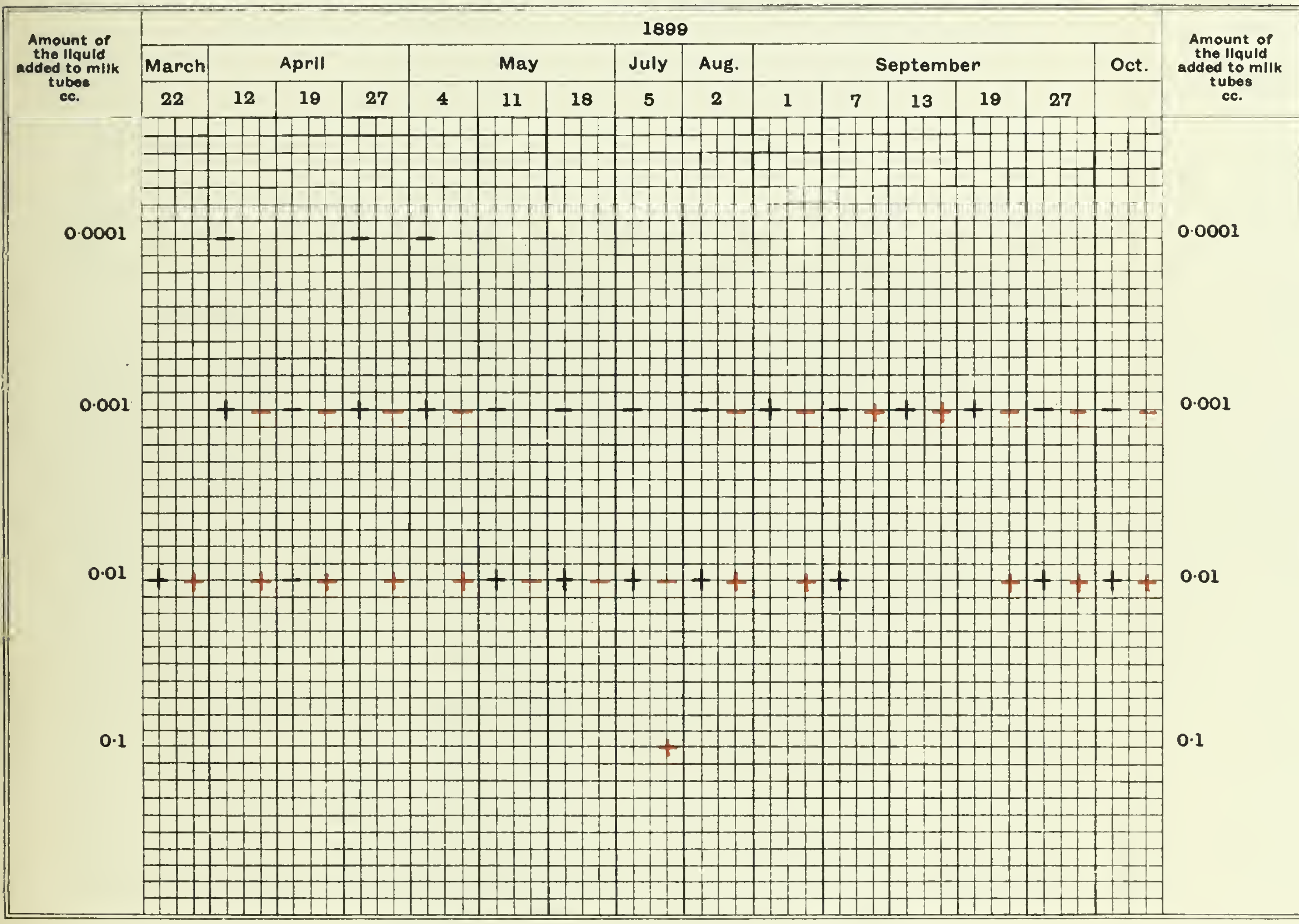


DIAGRAM 8.

Showing the number of spores of Bacillus Enteritidis Sporogenes in Crossness crude sewage, and in the effluent from the 13 ft. coke-bed.



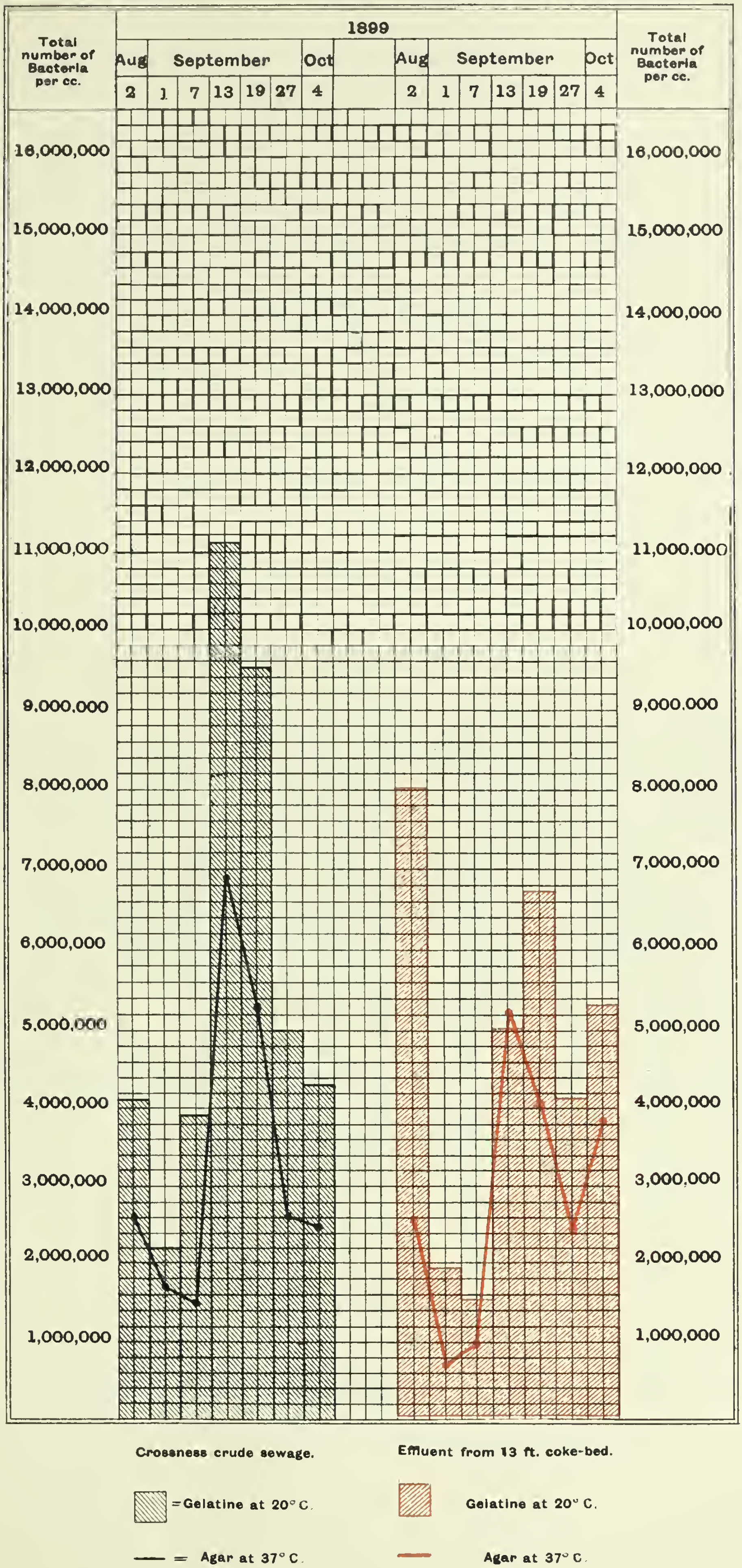
The sign + signifies the presence, and the sign — the absence, of the spores of Bacillus Enteritidis Sporogenes.

± = Crossness crude sewage.

± = Effluent from 13 ft. coke-bed.

DIAGRAM 9.

Showing the total number of Bacteria (Gelatine at 20° C. Agar at 37° C) in Crossness crude sewage, and in the effluent from the 13 ft. coke-bed.



London County Council.

BACTERIAL TREATMENT OF CRUDE SEWAGE.

FOURTH REPORT

BY

DR. CLOWES.

EXPERIMENTAL TREATMENT

OF

LONDON CRUDE SEWAGE

IN

SETTLING-TANKS AND COKE-BEDS AT BARKING AND CROSSNESS.

PRESENTED

To the Main Drainage Committee of the Council,

BY

PROFESSOR FRANK CLOWES, D.Sc. (Lond.), F.I.C.

(Chief Chemist to the Council),

On April 17th, 1902.

JAS. TRUSCOTT AND SON, LTD., PRINTERS, SUFFOLK LANE, CANNON STREET, E.C.

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BACTERIAL TREATMENT OF CRUDE SEWAGE.

I.—BRIEF SUMMARY OF THE ORIGIN, METHOD AND RESULTS OF THE EXPERIMENTAL BACTERIAL TREATMENT, WITH A STATEMENT OF CONCLUSIONS AND RECOMMENDATIONS.

Introductory.

The period of experimental treatment by bacterial agency at the Council's Outfalls has for the present been concluded, and the time appears opportune therefore for briefly stating why the experiments were undertaken, the nature of the experiments, the results which have been arrived at, and the recommendations which they suggest.

Origin of the Experimental Bacterial Treatment.

The whole of the raw, unsettled sewage of the Metropolis was formerly allowed to flow without any previous treatment into the Thames. The result was that the stream, more especially in summer time, became insupportably foul. The foulness arose partly from sewage mud or sludge deposited on the foreshores, partly from black sewage scum floating on the surface of the river, but also from putrid changes occurring in the sewage substances dissolved in the water itself.

It was decided to remove the main source of this nuisance by subjecting the sewage to straining or screening, and then to settling or subsidence, and to pass the more or less clear effluent from this settling process into the Thames many miles below London. Under this scheme the coarse screenings are now disposed of on farm land and the foul settled matter, or sludge, is carried out and discharged on a falling tide in the estuary. The sedimentation of the sewage has in recent years been much facilitated by the addition in moderate proportion of chemical solutions.

The above treatment, which is still in operation at the Outfalls, has prevented entirely the fouling of the foreshores and of the river surface with sewage sludge.

Those who proposed the above remedial measures, however, stated that the sewage effluent would still carry into the river a large amount of putrescible matter in solution, and recommended that, as opportunity occurred, the effluent should be further purified by land treatment or by other means, before it entered the river.

This further treatment has never yet been attempted on the large scale. No suitable land for land treatment existed at the Sewage Outfalls, and no other method of treating the effluent was known at the time.

The Massachusetts experiments on the treatment of sewage effluent in coke-beds, which enabled the bacteria present in the sewage to effect the necessary additional purification, were subsequently published. They appeared suitable to the purpose in view, and the Main Drainage Committee of this Council accordingly authorised my predecessor to start an experimental trial of the process at the Council's Outfalls.

At the time of my appointment as Chemical Adviser to the Council, the results arrived at by my predecessor were so promising that I strongly recommended their continuance on an extended scale; and for four years, with the assistance of the Chemical staff and with the co-operation of the Superintendents at the Outfalls, I have conducted this experimental purification of the sewage effluent, and have arrived now at results and conclusions which I am convinced are of the greatest importance, and are worthy of the most serious consideration of the Committee and of the Council.

Description of the Bacterial Experiments.

When I recommended the Committee to continue the experimental treatment, there was a large bacterial coke-bed, one acre in area, at the Northern Outfall which

was dealing with a small portion of the present effluent before it entered the river. This bed was arranged only to treat the chemical effluent; it was not of satisfactory construction, nor was it filled with suitable coke material. Further, it was impossible, owing to its low level, to empty it at all states of the tide, and accordingly it could not be filled as often as was necessary, in order to obtain the knowledge which was required. At the desire of the Committee, however, this bed has been maintained in action for over eight years, and it is now still giving admirable results in purifying the present sewage effluent.

But with the sanction of the Committee I have had in constant operation, and under most careful observation, a series of smaller coke-beds. These beds have received a special supply of raw sewage which came direct from the main sewer, and was entirely unmixed with chemicals. The process of working these beds has been subject to constant improvements and extensions, which have been suggested by experience and observation. I will only here describe the final method of experimental treatment which has been adopted.

The raw sewage, which has been screened from its coarser matters only, is pumped continuously into a settling tank, the rate of supply being so adjusted to the capacity of the tank that the sewage remains about six hours in the tank before it flows away through an elbow pipe from beneath the surface of the liquid into the coke-beds.

In this tank practically the whole of the suspended or floating particles of the sewage settle as sludge, and are allowed to remain undisturbed. It is found that a considerable proportion of this sludge disappears by bacterial action. During the first period of six months, before the bacterial action was fully started, 25·6 per cent. of the sludge disappeared, and during a subsequent similar period more than 50 per cent. of the sludge was removed by bacterial action. The portion which disappeared was the most putrescible portion of the sludge, which is at present carried to sea in the Council's sludge boats. Its disappearance would reduce the freight which these boats are required to remove. But it is probable that a considerable further reduction in the "sludge" cargoes might be effected by properly devised detritus settling tanks in which road sand would subside, and from which it might be removed to the marshes without giving offence. This reduction in the amount of sludge, which is secured by bacterial action alone, would be of the greatest importance.

The sewage as it flows from the settling tank is less pure than the effluent which is at present discharged into the river at Crossness, and is quite unsuitable for direct discharge into the stream. But by the subsequent coke-bed treatment it is rendered sufficiently pure to support the life of fish, and to insure it against undergoing even in summer time any offensive change.

In the experimental treatment, the settled sewage is therefore allowed to flow into a coke-bed, which is a tank filled with suitable coke fragments to a depth of six feet. As soon as the bed is filled to the surface of the coke, the supply is stopped, and the sewage liquid is allowed to remain in contact with the coke for two hours. It is then drained off from the bottom of the bed, and constitutes the "bacterial effluent." After the liquid has flowed away, the coke-bed remains empty for two hours, and is then refilled with a fresh supply of the settled sewage, which is treated in precisely the same way as the preceding charge. The coke-bed receives and purifies four charges of settled sewage in the twenty-four hours.

Conclusions arrived at by the Experimental Treatment.

The points which have been established by the experimental work are the following:—

1. That by suitable continuous undisturbed sedimentation the raw sewage is deprived of matter which would choke the coke-beds, and the sludge which settles out is reduced in amount by bacterial action to a very considerable extent. This reduction might undoubtedly be increased by the preliminary removal of road detritus.

2. That the coke-beds, after they have developed their full purifying power by use, have an average sewage capacity of about 30 per cent. of the whole space which has been filled with coke.

3. That the sewage capacity of the coke-bed, when the bed is fed with settled sewage, fluctuates slightly, but undergoes no permanent reduction. The bed does not choke, and its purifying power undergoes steady improvement for some time.

4. That coke of suitable quality does not disintegrate during use.

5. That the "bacterial effluent" of settled sewage from the coke-beds does not undergo offensive putrefication at all, even in summer heat, and can never become offensive. That this effluent satisfactorily supports the respiration of fish.

6. That the use of chemicals is quite unnecessary under any circumstances when the above method of treatment is adopted.

Recommendations founded on the above conclusions.

It would appear desirable, therefore, without delay, to commence the treatment of the London sewage by the above bacterial method. The construction of the necessary works will take time and will involve expenditure, but unless it is taken in hand, all considerations tend to show that owing to the increased abstraction of water by the water companies, both at their existing intakes and at the newly constructed reservoirs for storm water at Staines, a large portion of the lower river will continuously deteriorate. This deterioration would arise from the increase in the amount of the discharge of sewage effluent and the decrease in the upper river flush. Possible trouble arising from these causes will be absolutely prevented by adopting, under proper conditions and on a large scale, the treatment which has been strikingly successful on the experimental scale. It must be remembered that the condition of the river cannot be improved by any suddenly adopted action.

If the treatment is introduced without delay and is gradually extended it may reasonably be expected that the increasing deterioration in the lower river water will first be checked and will ultimately be prevented; while the gradual development of the treatment will cause the expenditure to be spread over a period of years, and will prevent it from being unduly burdensome.

It must be remembered that the present settling channels would serve, as at present, for settling purposes, but by the altered method of working them they would also act as sludge destroyers. They should, however, undoubtedly be preceded by grit chambers. It must be further borne in mind that the expense involved in the purchase and application of chemicals would be dispensed with.

By a considerate adoption of the method, therefore, the expenditure might be distributed, and need not be large at any one time.

A fuller statement of details is supplied in subsequent sections.

Summary of Information furnished by Towns and Districts in which the Bacterial Treatment of Sewage has been employed.
Treatment of Sewage has been employed.

At the end of this report a tabulated statement of the results of the Bacterial or natural process of treating sewage in some of the principal centres throughout the country, is appended. It has been thought that this information would prove useful as a means of comparing the results of the various experimental and permanent installations with the results obtained by the London County Council, and would show how extensively the method is already in use. It would also serve as a guide in extending the use of this method of treating sewage to fresh centres of population.

Some of the authorities have furnished most exhaustive records of the experiments and work which they have carried out, and, with the exception of Glasgow and Huddersfield, the opinion expressed is entirely in favour of the treatment of sewage in bacteria beds by a method suited to the requirements of the district and to the character of the sewage.

At Glasgow the results of the treatment of sewage in experimental bacteria beds indicated a purification from putrescible matter of 95 per cent., while the open septic tank was the means of reducing the amount of sludge by 54 per cent. Similar results have been accepted as satisfactory at other centres. The objection to the use of bacteria-beds at this centre appears to be that the area required for their installation at the Dalmuir Sewage Works for the treatment of 49 million gallons, would be 164 acres, while the system of treatment by lime and sulphate of alumina could be satisfactorily carried out on a superficial area of 23 acres. By this latter method it is claimed that every trace of suspended matter is removed, and that 30 per cent. of purification from putrescible matter is effected.

At Huddersfield the sewage is of an exceptional character, since 30 per cent. is derived from manufacturing processes, almost wholly woollen, and it contains a quantity of soap, fat, and dyes, and a variety of chemicals used in the dyeing and finishing of woollen goods. The best results were obtained by treating the sewage with a small quantity of lime and sulphate of iron, followed by double contact in

bacteria-beds. The beds which were used for this purpose retained their capacity much better than those which dealt with either the crude sewage or with the septic tank effluent.

A careful consideration of all the information obtained from the various centres where bacterial treatment has been tried convinces me that the process has been uniformly successful when the construction and use of the necessary plant has been reasonably and properly carried out. The only exception that appears possible to this general statement is interference which is caused by the sewage being of a very unusual character.

The following summary includes the opinions which have been expressed by all the authorities who have tried the bacterial system of sewage treatment and have reported to me on their work:—

Accrington—The whole of the sewage is treated by the bacterial method, and the results are satisfactory.

Acton—The experimental treatment was successful, and the effluent was approved of by the Thames Conservancy. The whole of the sewage is to be treated bacterially.

Aldershot—"When this is done (the construction of secondary coke-beds) I think Aldershot "will have every reason to be proud of the manner in which it has solved the very difficult "question of how to dispose of the sewage in a satisfactory manner, and will have one of the "most efficient systems in the kingdom." Annual Report of the Medical Officer of Health for 1901.

Aylesbury—The result of the treatment is considered to be satisfactory.

Barnsley—The result of a temporary experiment was satisfactory.

Birmingham—The Engineer to the Birmingham, Thame and Rea District Drainage Board, states—"The results obtained were perfectly sufficient to warrant me in saying that the sewage "of the Birmingham, Thame and Rea District can be efficiently treated on prepared bacteria-"beds."

Bristol—The degree of purity of the effluent from bacteria-beds is satisfactory.

Burnley—"We are convinced that the scheme adopted by your Committee will prove "an efficient one, and that the treatment of the sewage of the Borough will be carried out in a "more satisfactory manner and with less cost by this system (bacterial tank supplemented by land) "than it could be by any other which has come under our notice." Highways and Sewage Department of the County Borough of Burnley, Report on Sewage Disposal, 23rd April, 1901, p. 20.

Bury—"From the results obtained up to the present, the Corporation have decided to "extend the works on similar lines" (*i.e.*, chemical treatment followed by subsidence and by bacteria-beds).

Chorley—"If we had to start *de novo*, we should adopt exactly the same principle" (chemical precipitation followed by bacterial treatment).

Darwen—"Having already proper precipitation tanks and filter (coke) beds, we do not "think it advisable to change the system as we are obtaining satisfactory results, but, if a new "scheme were to be laid down, many modifications would be made."

Glasgow—The effluent from the bacterial treatment was stated on a recent visit from an officer of the Council, to be entirely satisfactory and non-putrescible.

Huddersfield—"Owing to the final effluent being frequently unsatisfactory, and also "to the rapid decrease of the capacity of the coarse bed, the use of this system on a large scale "is not contemplated. The sewage of Huddersfield is of an exceptional character."

Hyde—A complete scheme of sewage treatment, based upon the results of experiments of bacterial treatment, has been submitted to the Local Government Board for approval.

Keighley—The Borough Engineer states—"In my opinion, bacterial treatment ought to "satisfy any river authority. My Council do not intend putting down a permanent installation "so long as our present system of intermittent land filtration is satisfactory. There is no doubt "the beds will gradually become choked, but to cleanse or renew, I think, would be cheaper than "chemical treatment."

Kettering—"The provision of filter-beds has very much improved the character of the "effluent."

Leeds—The Chairman of the Leeds Sewerage Committee states that the results from a process of continuous bacteria-bed treatment "are very good indeed, giving a purification of "95 per cent."

Leicester—A process of bacteria-bed treatment followed by final purification on land has been favourably reported upon by the Borough Engineer and Surveyor. See report to the Highway and Sewerage and Sewage Works and Farms Committee, 1900, p. 122.

Lincoln—The City Surveyor says—"The external authorities (through whose districts the "effluent stream runs), who previously had been dissatisfied with our farm and polarite-bed "effluents, have expressed themselves satisfied with our bacteria-bed effluent, we therefore are "completing an installation to deal with all our sewage."

Manchester—Extract from the Annual Report of the Rivers Department for the year ending 27th March, 1901, p. 74—"The result of the work recorded in the foregoing "pages, while emphasising the necessity for care in the construction and management of sewage "purification work, gives the Committee every encouragement in carrying out the scheme for the "bacterial treatment of Manchester sewage according to the general principles advised in the "Experts' Report, 1899, and sanctioned by the Council on September 5th, 1900." The experts recommended preliminary sedimentation and screening followed by bacteria-tank and bacteria-bed treatment.

Middleton—The Borough Surveyor states—"If of sufficient area and properly managed, "they (bacteria-beds) will act satisfactorily."

Nelson—The results obtained by experimental bacteria-beds were quite satisfactory.

Oldham—Extract from a report entitled, "The Treatment of Oldham Sewage in the year 1900," by the Medical Officer of Health, p. iii—"With the exception of a few days during the "year, when the weather was very dry, the method (bacterial treatment) has been entirely "successful."

Ormskirk—The Surveyor states that—"The results obtained at the council's farm, after "the sewage running through lagoons into settling tanks and then run on to the land and after- "wards through the coke breeze filter beds, are very satisfactory and meet the requirements of "the authorities."

Oswestry—The Town Clerk states that they "have no doubt as to the success of the "bacterial treatment. Our results are continuously satisfactory, and the effluents keep free from "putrescence."

Reigate—"The result of three years' searching trial is so satisfactory as to encourage the "Council to sanction the outlay and adopt a scheme for treating the whole of the sewage of the "Borough on the lines adopted by the experimental plant."

Salford—The Borough Engineer states that "we can fully depend upon the bacteria-beds "to give a satisfactory effluent, even when working night and day, almost without intermission." Permanent beds to treat the whole of the sewage are being constructed.

Sheffield—"The degree of purification obtained has been uniformly satisfactory. The loss "of capacity of the beds continues, and experiments are being conducted with the object of "reducing this as much as possible. Permanent works on bacterial principles are contemplated, "but working details cannot be decided upon until further experiments are completed."

Southport—The Medical Officer of Health says that the "bacteria-beds are only small "experimental ones. . . . They have, however, worked entirely to our satisfaction so far as we "have tested them, and they have always produced a clear and non-putrescible effluent."

Walsall—The Borough Surveyor states that in the Bloxwich district first-class results are being obtained in the bacterial treatment of the sewage.

Wolverhampton—The Town Clerk states that the results of the coke-bed treatment are good, but that a permanent installation is doubtful owing to the presence in the sewage of iron salts in large quantities.

York—In a Report to the Sewerage Committee, dated October, 1901, the City Engineer states (on p. 41), with respect to an experimental plant consisting of an open septic tank and continuous treatment in coke-beds, that the results were excellent and the filtrate was non-putrescible. That "the system is adaptable for larger quantities per square yard than any other "experiment," and that there is no loss of liquid capacity in the coke-bed.

Short Summary of the Evidence given before the Royal Commission on Sewage Disposal.

It has been suggested that the results arrived at by the Royal Commission on sewage disposal would be of great value to the Main Drainage Committee of the Council. The Commission have now published their minutes of evidence, and a careful perusal of the evidence given by the independent experts, including engineers, bacteriologists and chemists, shows that they are in general agreement in maintaining that the only known method of producing a satisfactory sewage effluent on a large scale is by the adoption of one or other of the various systems of bacterial treatment.

The bacteriologists gave evidence to the effect that the purification of sewage was a combined anaërobic and aërobic process, and that the best results were obtained by a more or less perfect anaërobic treatment, followed by an aërobic treatment. The evidence in support of this view tendered by Professor Marshall Ward and by Dr. Sims Woodhead, is mainly based on theoretical grounds, and will be found to be of great value and interest.

On the other hand, Dr. Adeney, Colonel Ducat and others claim that their processes are entirely aërobic in their character. In face of the above evidence this contention appears very doubtful, and it is more likely that the one treatment succeeds in combining the two processes.

The great majority of the witnesses agree that crude sewage cannot be successfully treated by contact beds alone, since, although the results are good and a non-putrescible effluent is produced, the liquid capacity of the beds diminishes so rapidly that they soon become useless.

In order to prevent this choking of the beds and to maintain their liquid capacity, almost all of the schemes described include a preliminary process of sedimentation which is in most cases also rendered an anaërobic or so called "septic" process. Its main objects are to free the sewage from mineral suspended solids and to cause the complex suspended organic solids to pass into solution and to become simplified in nature. In the subsequent aërobic process, usually carried out in coke-beds, opinion is divided as to the respective merits of a continuous and of an intermittent supply. It must be said that those who support the continuous treatment make out a good case so far as the results obtained are concerned. The continuous system seems to produce nitrates in larger amount than does the intermittent system, but at the same time the effluent is by no means as free from suspended solids which appear to be washed through the bed. Some special method of distribution of the liquid to the bed is required by the continuous treatment, and this is not only a cause of additional expenditure but also of additional trouble in maintenance as compared with the intermittent system of supply.

It is generally agreed that the liquid capacity of a new bed falls rapidly when it is first started, but it is maintained that this decrease soon ceases, and that a permanent capacity can be

insured by an intelligent working of the bed. The extreme capacity values vary from 20 to 33 per cent. of the whole space represented by the bed when full—including both coke and liquid. An average of about 30 per cent. would represent the average permanent capacity of a working bed.

Three fillings of the beds per day were advocated by most of the witnesses, and the quantity of sewage per day dealt with by an acre of bed, three feet in depth, was placed at not more than 800,000 gallons. This is undoubtedly understating the capabilities of the bacterial system. Deep beds have given quite as good purifying results as shallow beds.

The quantity of sludge which disappears by anaërobic action in the settling or "septic" tank is variously estimated at from 20 to 60 per cent. of the whole amount deposited in the tank. It is curious to note that Mr. Whittaker claims that no sludge disappears in his septic tank, though he admits that large quantities of gas are found. (Questions 5742-65). In cross-examination on this matter, he can hardly be said to have proved his statement.

It was generally admitted that a septic tank effluent is capable of being rendered non-putrescible by one contact in an aërobic bed.

Professor Letts, in his evidence with reference to the purification of Belfast sewage, stated that salt prevented the formation of nitrates. This perhaps accounts for the low proportion of nitrates found in the effluents from the Crossness beds, as compared with that found in the effluent from the Barking beds, since Crossness sewage contains an abnormal quantity of salt.

Dr. Adeney's evidence will be found to have a bearing on the present and probable future condition of the river Thames.

Briefly, it may be said that although the experts differed in small matters of detail, they agreed in the broad principles of sewage purification by bacterial means, and their evidence is a strong confirmation of the results obtained by the experimental work carried out at the Council's Outfalls.

II.—EXPERIMENTAL BACTERIAL TREATMENT OF CRUDE SEWAGE AT THE NORTHERN OUTFALL WORKS (BARKING).

1.—TABULATED LIST OF THE EXPERIMENTS AND OF THE BACTERIA-BEDS.

The various experiments carried out at the Northern Outfall Works in connection with the bacterial or natural treatment of sewage are included in the following list.

The bacterial treatment of effluent from chemically treated and sedimented sewage in a coke-bed of one acre area.

The treatment of raw sewage in bacteria-beds, with and without previous settlement.

(*a*) Without previous settlement.

In beds of Kentish ragstone and of coke, from September 22nd, 1898, to April 15th, 1899. (Series I.)

In coarse and fine coke-beds, from July 4th, 1899, to May 19th, 1900. (Series II.)

(*b*) With previous settlement.

In coarse and fine coke-beds, from November 7th, 1900, to August 10th, 1901. (Series III.)

The one-acre coke-bed, as originally constructed, was three feet in depth, and it was composed of unsifted pan breeze. In 1898 it was increased in depth to 6 feet, by placing on the top of the old bed 3 feet of sifted coke fragments about the size of walnuts ; it has not undergone further alteration in depth.

It was first used as a 6 foot coke-bed, on April 29th, 1898, and since May 12th, 1898, it has been dealing almost continuously with effluent from the chemically treated and sedimented sewage.

This coke-bed has been reported upon in the Third Report, pp. 13 and 14, and the analytical results are given on pp. 25 to 34 of the same Report. Later details of the work of this coke-bed are given on pp. 9, 10, 24, 28 and 29 of this Report.

For the purpose of carrying on other experiments on the bacterial or natural process of sewage purification, four galvanised iron tanks were used. In order to facilitate the use of these tanks in pairs, for the treatment of sewage in two consecutive coke-beds by so-called "'double contact," two of the tanks were fixed at a higher level than the other two; by this arrangement the effluent from a higher tank could be allowed to flow into a lower tank by gravitation.

The following table indicates the various uses to which these tanks have been put during the whole of the bacteria-bed experiments—

Date.	Upper tanks.*		Lower tanks.*	
	No. 1.	No. 2.	No. 1.	No. 2.
1898. 22nd Sept.	Kentish ragstone-bed, primary	Coke-bed, primary ...	Kentish ragstone-bed, secondary	Coke-bed, secondary.
1899. 15th April.		End of Experim	ents of Series I.	
1899. 4th July.	Primary, coarse coke-bed	Primary, coarse coke-bed	Secondary, coarse coke-bed	Secondary, fine coke-bed
1900. 19th May.		End of Experim	ents of Series II.	
1900. 7th Nov.	Settling tank A ...	Settling tank B ...	Single coke-bed A (coarse)	Single coke-bed B (fine)
1901. 10th Aug.		End of Experim	ents of Series III.	

2.—SUMMARY OF THE PREVIOUSLY REPORTED DETAILS OF THE EXPERIMENTS IN THE BACTERIAL OR NATURAL TREATMENT OF SEWAGE AT THE NORTHERN OUTFALL WORKS, WITH SUCH ADDITIONS AS ARE NECESSARY IN ORDER TO COMPLETE THE INFORMATION UP TO THE END OF 1901.

(*a*) The One-acre Coke-bed dealing with the Effluent from Chemically Treated and Sedimented Sewage.

The one-acre coke-bed has been dealing almost continuously with effluent from the chemically-treated and sedimented sewage since May 12th, 1898. Full particulars of the working of the bed up to April, 1900, and details of the chemical analyses of the liquid supplied

* Each tank was originally 4 feet square and 6 feet deep ; they were afterwards increased to 10 feet deep.

to it, and of the effluent obtained from it, up to December, 1899, were published in the Third Report on the Bacterial Treatment of Crude Sewage, on pp. 13 and 14 and pp. 25 to 34. The following particulars and the table No. 1 on pp. 28 and 29 bring the publication of the information respecting the bed up to the end of December, 1901.

Immediately prior to April, 1898, the bed had been increased in depth from 3 feet to 6 feet, by the addition of sifted coke fragments about the size of walnuts, but it was discovered some time afterwards, that the lower 3 feet of the bed, which consisted of unsifted "fine pan breeze," had become very much consolidated, and that the effluent drained away from it very slowly; the effective portion of the bed was, therefore, the upper 3 feet which consisted of sifted coke.

The average quantity of effluent dealt with by the bed at each filling, during the years 1900-1 was 344,969 gallons, whereas during the period from May 12th, 1898, to December 30th, 1899, the average quantity per filling was 519,367 gallons. This difference is probably due to—

i. The continued consolidation of the lower three feet of the material composing the bed.

ii. The difference in the average number of hours during which the bed was allowed to drain throughout the two periods. From May 12th, 1898, to December 30th, 1899, the average number of fillings per day was 1·05, whereas during the two years 1900-1, the average number of fillings per day was 1·55.

The time for filling the bed was generally so selected that the effluent could be discharged into the river at low water; this was done in order to avoid the expense of pumping. Under this arrangement two fillings per 24 hours were usually made. The time-table for the bed was as follows—

Time occupied in filling	$1\frac{1}{2}$ hours
Time occupied in standing full (contact period) ...	2 ,,
Time occupied in emptying	$2\frac{1}{2}$,,
Time occupied in standing empty (aëration period) ...	6 ,,

The high efficiency of the bed has been very well maintained, but it should be borne in mind that this bed has been dealing only with the effluent from chemically precipitated sewage and has therefore had a much smaller amount of purification to effect than the beds which have dealt with crude sewage.

The average purification of the crude sewage which has been effected during the past two years by the bacterial action of the bed in conjunction with the previous chemical treatment and sedimentation was 91·2 per cent., as measured by the relative quantities of oxygen absorbed from permanganate by the total putrescible matter (both suspended and dissolved) in the crude sewage and in the coke-bed effluent. The average purification effected on the "chemical" effluent by the coke-bed treatment, when estimated in a similar manner, was 85·6 per cent., whereas it was only 81·8 per cent. during previous periods when these estimations were made, namely, from November 8th, 1898, to January 21st, 1899, and from October 18th to December 31st, 1899.

The treatment of effluent from the chemically treated and sedimented sewage is being continued in this bed.

(*b*) The Double Bacteria-beds of Kentish Ragstone and of Coke, dealing with Crude Unsettled Sewage at the Northern Outfall Works. (Series I.)

These experiments were undertaken in order to determine whether a body consisting largely of carbonate of lime and possessed of neutralising power on acids, was more favourable to bacterial purification than a neutral substance like coke.

The treatment of crude unsettled sewage in the bacteria-beds of Kentish ragstone and of coke, was carried out during the period from September 22nd, 1898, to April 15th, 1899. The full details of the experiments were published in the Third Report on the Bacterial Treatment of Crude Sewage on pp. 7 to 10 and on pp. 17 to 19.

The material of the beds was contained in galvanised iron tanks four feet square and six feet deep; these were filled with the material to a depth of five feet. The coke-beds consisted of a primary bed composed of coarse fragments of coke, and of a secondary bed composed of fine fragments of coke; these two were known as the coarse and fine coke-beds respectively. The ragstone-beds consisted of a primary bed composed of coarse fragments of Kentish ragstone, and of a secondary bed composed of fine fragments of Kentish ragstone; they were known as the coarse and fine ragstone-beds respectively. The material of both the coarse beds was of such a size as would pass a 4-inch mesh and be rejected by a $\frac{1}{2}$-inch mesh; the material of the fine beds was of such a size as would pass a $\frac{1}{2}$-inch mesh and be rejected by a 1-16th inch mesh.

The method adopted in dealing with these beds, was to fill both of the primary beds as quickly as possible with crude sewage which had passed through a screen of $\frac{1}{2}$-inch mesh. The beds were allowed to remain full for two hours, and the effluent from each of the primary beds was then allowed to flow into the corresponding fine beds. The fine or secondary beds were allowed to remain full for two hours, and the final effluent was then allowed to flow out.

Each bed received one filling in the 24 hours for about the first four months of the time during which the experiments lasted, and two fillings for about the last three months.

The average percentage purification effected by the beds, as measured by the relative quantities of oxygen absorbed from permanganate by the crude sewage and by the effluents from the various beds, is set forth in the following table—

	During the period when the beds were filled		During the period of the whole experiment.
	once per day.	twice per day.	
Coarse coke-bed	22·3	22·6	22·5
Coarse ragstone-bed...	20·2	21·0	20·6
The combined coarse and fine coke-beds ...	64·9	61·5	63·2
The combined coarse and fine ragstone-beds	46·8	51·6	49·1

The effluents from the primary beds killed gold and silver fish in a few hours, but those from the secondary beds sustained fish life as readily as fresh tap-water does.

The capacity of the coarse beds was measured after they had been in use for about one week, and again after they had been in use for 24 weeks. The loss in capacity during the 23 weeks, stated as a percentage of the total capacity of each bed, was as follows—

Coarse coke-bed ... ... 6·4 per cent.
Coarse ragstone-bed ... ... 5·2 ,,

The fine beds suffered no loss in capacity throughout the experiments.

The experiments with these beds indicated—

i. That coke produced better results than Kentish ragstone when used in a bacteria-bed, although the latter produced more nitrates.

ii. That bacteria-beds rapidly decrease in capacity when they are dealing with unsedimented sewage.

iii. That when bacteria-beds have attained their full purifying power, they can deal as efficiently with two fillings of sewage per day as with one.

iv. That secondary beds effect a considerable additional purification, and dealing as they do with clear liquid, free from suspended matter, they do not decrease in capacity.

(c) THE COARSE AND FINE COKE-BEDS, NINE FEET NINE INCHES IN DEPTH, DEALING WITH CRUDE UNSETTLED SEWAGE AT THE NORTHERN OUTFALL WORKS. (Series II.)

These experiments were undertaken with the object of ascertaining the effect, if any, of increased depth of bed on the purification effected.

The iron tanks used in the last experiment, were deepened by bolting on four feet of iron superstructure, the joints being made watertight. The tanks were filled with coke to a depth of 9 feet 9 inches, and these beds were worked in two series as follows—

Series A consisted of—
(1) A primary coarse bed (A).
(2) A secondary coarse bed (A 1).

Series B consisted of—
(1) A primary coarse bed (B).
(2) A secondary fine bed (B 1).

The coarse beds were composed of coke fragments which would pass a 2 inch mesh and be rejected by a ½ inch mesh. The fine bed was composed of coke fragments which would pass a ½ inch mesh and be rejected by 1-16th inch mesh. The sewage supplied to the primary beds was similar to that used in the previous experiment. The average percentage purification effected, as measured by the relative amounts of oxygen absorbed from permanganate by the dissolved putrescible matter in the crude sewage and in the final effluents, is set forth in the following table—

	During the period when the beds received		
	three fillings per week. About two months.	six fillings per week. About three months.	twelve fillings per week. About five months.
Primary coarse bed A	43·9	43·6	48·9
Primary coarse bed B	43·5	43·9	50·2
The combined beds of Series A	62·3	62·8	64·2
,, ,, ,, B	79·1	77·0	72·2

The alteration in the capacities of the various beds during the experiments is indicated by the following records of the measurements made at the beginning of the experiments and after the beds had been in use for about eight months, on the 7th February, 1900. A third set of measurements is added ; these were made after the publication of the Third Report. The capacities are stated as percentages of the cubical capacity of the total space occupied by the bed, assuming the coke to be absent.

	29th May, 1899 (dry coke)*	7th Feb., 1900.	Decrease.	15th March, 1900.	Decrease.
Primary coarse bed A ...	68·7	21·8	46·9	20·3	1·5
Primary coarse bed B ...	70·3	21·2	49·1	17·9	3·3
Secondary coarse bed A1...	61·7	50·6	11·1	50·6	nil.
Secondary fine bed B1 ...	53·1	44·4	8·7	44·4	nil.

During these experiments the temperature of the sewage and of the effluents from the various coke-beds was recorded. The average of these records shows that there was a fall of about 7 degrees Fahrenheit in the temperature of the liquids in the beds, but that while the beds were standing empty their temperature increased by about 3 degrees. The temperature of the atmosphere during these examinations was on the average 10 degrees lower than that of the sewage before it passed on to the coke-beds, and the tanks containing the beds were freely exposed on all sides to the cooling action of the air.

The air in the interstices of the coke at the bottom of the primary beds was analysed, and estimations of the proportions of oxygen and of carbon dioxide (carbonic acid gas) present, were made. The average results of these estimations are given in the following table—

	After the bed had remained empty for an average period of 5 hours.	After the bed had remained empty for an average period of 21 hours.	Composition of fresh air.
Oxygen	8·0 per cent.	10·3 per cent.	20·96 per cent.
Carbon dioxide ...	5·7 „	5·7 „	0·04 „

The amount of ntirification effected by the beds is indicated in the following table—

	Average quantity of oxidised nitrogen present in the sewage and in the effluents from the beds.					
	During the period July 4th, 1899, to December 30th, 1899.		During the period January 1st, 1900, to May 19th, 1900.		During the whole period July 4th, 1899, to May 19th, 1900.	
	Nitrous nitrogen.	Nitric nitrogen.	Nitrous nitrogen.	Nitric nitrogen.	Nitrous nitrogen.	Nitric nitrogen.
Crude sewage	0·0057	0·2289	0·0291	0·0783	0·0162	0·1617
Effluent from primary coarse bed A	0·1331	0·6391	0·0747	0·3937	0·1069	0·5291
„ „ „ „ B	0·0921	0·5089	0·0582	0·3297	0·0769	0·4289
„ secondary „ „ A1	0·1096	1·3256	0·1187	1·0325	0·1137	1·1948
„ „ fine „ B1	0·0584	2·2659	0·0540	2·2430	0·0564	2·2557

3.—PARTICULARS OF THE EXPERIMENTS ON THE BACTERIAL OR NATURAL PROCESS OF SEWAGE PURIFICATION AT THE NORTHERN OUTFALL WORKS (BARKING) WHICH HAVE NOT BEEN PREVIOUSLY REPORTED.

(a) The Purification of Crude Sewage by Passage through a Settling Tank and Subsequent Treatment in a Coke-bed. (Series III.)

Since the loss in capacity of the bacteria beds appeared to have been caused by the suspended matter present in crude sewage, a preliminary process of sedimentation was next tried.

This series of experiments was carried out between November 7th, 1900, and August 10th, 1901. It was the third series of experiments with crude sewage in coke-beds at the Northern Outfall and, following previous reports, brings the publication of the details of the experiments and of the analytical results of the whole of the experiments up to the end of the year 1901.

I.—*Particulars as to the arrangement of the tanks and of the beds.*

The four iron tanks used in connection with the previous experiments were used for this series in the following manner—

The two upper tanks, which were on a higher level than the others, and which had been used as primary beds in the previous experiments, were emptied of their coke, and were used as settling tanks (A and B). Each of these tanks was supplied with crude sewage from the mains by a $1\frac{1}{2}$-inch iron pipe which dipped into the tank to a depth of 7 feet from the top.

* It must be remembered that the dry coke would itself absorb liquid.

In order to secure even distribution of the sewage, and to prevent the sediment of sludge on the bottom of the tank from being disturbed, the crude sewage flowed upon a board 8 inches square, fixed about 6 or 7 inches below the open end of the feed pipe.

A 1-inch iron pipe was used in each tank as a syphon for conveying the settled sewage from the settling tanks to the coke-beds in the lower tanks. One end of each of these pipes was continued to a depth of 5 feet below the top of the settling tank, the other end of each syphon pipe discharged the sewage upon the first of a series of three consecutive wooden platforms; the last platform of each series was perforated and was placed about 2 feet above the surface of the coke in the lower tanks. The object of these platforms was to secure aëration of the settled sewage.

The total capacity of each of the subsidence tanks was 1,000 gallons, but the depth at which the tanks were worked was only 9·5 feet and gave a working capacity of 950 gallons.

The two lower tanks were used for the coke-beds. The bed which was worked in connection with settling tank A was known as the "Coarse Coke-bed A." It was composed of the coke which had been used in connection with the previous series of experiments, and the size of the fragments was such that they would pass through a 2-inch mesh and be rejected by a ½-inch mesh.

The other tank was known as "Fine Coke-bed B." The coke of which it was composed had also been used before and was of such a size as would pass a ½-inch mesh and be rejected by a $\frac{1}{16}$-inch mesh. Both of the tanks were filled with coke to a depth of 6 feet. The beds were underdrained with perforated 2-inch iron pipes arranged as a "fourway," with three open ends, while the fourth end was connected with the outlet tap. Large pieces of coke were arranged around the pipes in order to prevent choking.

II.—*Method of working the tanks and beds.*

When the two settling tanks were first started they were filled with roughly screened crude sewage to within 6 inches of the top and this was allowed to settle for 24 hours; sufficient of the sedimented sewage to fill the coke-beds was then syphoned off to the beds. The sewage from tank A was always supplied to coke-bed A, while that from tank B always passed on to bed B. After the beds had been filled from the tanks, the latter were immediately filled up with fresh sewage, which was allowed to settle until it was time for the coke-beds to receive a fresh charge. This method of procedure was maintained throughout the experiments of Series III., except as regards the number of consecutive hours during which the sewage remained undisturbed in the settling tanks. After the coke-beds had been filled, they remained undisturbed for two hours; they were then emptied, and remained with air filling the interspaces until the time arrived for re-charging them with sewage. This rest period necessarily varied with the number of charges which the beds received during the twenty-four hours. The number of fillings per day ranged between one and three. The beds were filled at 4 a.m., 2 p.m. and 10 p.m. when they were receiving three fillings per day.

III.—*Particulars as to the number of times the coke-beds were filled.*

By reference to Table III., p. 32, it will be seen that the coarse coke-bed A was filled with settled sewage 287 times between November 8th, 1900, and August 6th, 1901, and that the fine coke-bed B was filled 313 times during the same period. Both of these coke-beds always rested on Sundays.

On several days during January, February and March, 1901, it was impossible to fill the coke-beds on account of the tanks having become frost-bound. This was due to their elevated position giving free exposure on all sides to the air.

Both beds rested from April 24th to May 5th, 1901. This was thought to be advisable because their purifying powers had apparently deteriorated. By reference to Table III. it will be seen that immediately before this period, the beds had been receiving three fillings per day for nine days; this was apparently too much work for the beds to deal with satisfactorily. It must be borne in mind that these beds were dealing with sewage which had undergone very imperfect sedimentation, on account of the small size of the settling tanks and the imperfect manner of feeding and discharging them; and it was further shown, later on, that the sewage had undergone very slight anaërobic or septic action in these tanks. The sewage supplied to the beds was therefore not in a suitable condition for undergoing rapid purification in the coke-beds.

The coarse coke-bed A rested also from June 6th to 27th, 1901, because it showed a decrease in the efficiency, which was apparently due to overwork.

The other days on which the beds rested were either public holidays or times at which the boilers of the engines were being cleaned, or days on which the pumps were being repaired.

IV.—*Relative to the action of the settling tanks.*

The settling tanks were primarily arranged for the purpose of intercepting the grosser suspended matter from the sewage which passed through them. Such matters consist principally of sand and road detritus and of substances chemically known as "cellulose," which include water-logged wooden refuse and the husks of cereals. Since sand and mineral road detritus are not acted upon by bacteria at all, and cellulose is only very slowly broken up by aërobic bacterial action, it follows that these substances should be intercepted, since, if they are allowed to enter the coke-beds, the capacity of the beds becomes very rapidly reduced.

It was anticipated that bacterial change would occur in the sediment, and the tanks were carefully watched in order to detect any signs of so-called "septic" or anaërobic bacterial action which might take place in them. On December 13th, 1900, an examination of the deposit in the settling tanks was made and indicated that some of the sediment or sludge had disappeared from the bottom of the tanks.

During the period of rest from July 12th to 16th, 1901, septic action occurred in the settling tanks, and large masses of sludge were lifted to the surface by the gas evolved during the anaërobic action. The sludge which had been deposited in the tanks was very much disturbed by this movement, as well as by the alteration of the level of the liquid in the tanks while the settled sewage was being syphoned off for the purpose of filling the coke-beds. Further, on account of the small size of the tanks some of the sludge, which had been lifted by the gas bubbles, was drawn through the syphon pipes and thus gained access to the coke-beds.

On January 28th, 1901, the settling tank A was thoroughly cleaned out and a fresh start was made.

Throughout the period of experiment the amount of suspended matter or sludge entering the tank in the crude sewage had been carefully determined, and it was known how much should be present as a sediment on the bottom of the tank. But when the quantity of this sludge was estimated, during the clearing out of the settling tank, it was found that the amount was considerably less than that which had entered the tank. No less than 20·2 per cent. of this total solid matter was found to have been liquefied by septic action between January 28th and August 6th, 1901, in settling tank A; this is equal to 37·4 per cent. of the solid organic matter in the sewage supplied to the tank. The reduction of the quantity of solid matter in tank B was only 6 per cent. of the total solids, or 12·8 per cent. of the solid organic matter in the sewage supplied to the tank between February 9th and August 6th, 1901.

The great difference between the amounts of septic action which had occurred in the two tanks is doubtless due to the fact that tank A, in which the septic action appears to have been the more pronounced, had not been disturbed during three weeks from June 5th to 28th, on account of the period of rest accorded to the coke-bed which was worked in connection with the tank A; whereas tank B was practically in continuous use. As has been already stated the disturbance of the sludge during working was considerable, and undoubtedly interfered with the septic action. There seems also little doubt that the low temperature of these tanks, due to their free exposure on all sides to the air, is inimical to bacterial change. Similar experiments carried out at the Southern Outfall, with settling tanks constructed in masonry and sunk in the ground, gave much more uniform and satisfactory results, and this appears to be due to their maintaining a higher and more uniform temperature, as well as to their feed being so arranged as to avoid disturbance of the sedimented sludge.

The amount of sludge produced weekly in each of the two subsidence tanks averaged about 9 gallons, and it contained 89·5 per cent. of moisture. The average quantity of sewage which passed through each tank was 1,620 gallons weekly in the case of tank A, and 1,412 gallons in the case of tank B.

V.—*As to the action of the coke-beds.*

The results of these experiments, as far as the action of the coke-beds is concerned, may be considered very satisfactory. Bearing in mind the small size of the settling tanks and the small amount of septic action which took place in them, the chemical condition of the final effluent and the small loss of capacity of the coke-beds compare very favourably with the results of other experiments and prove the great advantage of preliminary sedimentation.

The average percentage amount of purification effected by the combined action of the settling tank and of the coarse bed of Series A, as measured by the relative quantities of oxygen absorbed from permanganate by the dissolved putrescible matter in the crude sewage and in the final coke-bed effluent, was 51·8; the highest average purification effected by the double ragstone-beds with two fillings per day amounted to 51·6, but the double coke-beds of this series of experiments yielded the best results with one filling per day, when an average of 64·9 per cent. of purification was effected. It will thus be seen that the purification effected by the settling tank and coarse coke-bed of Series A was equal to that effected by the double ragstone-beds.

A more useful comparison between the results of the various experiments may be obtained by comparing the actual amount of purification effected by the individual beds on the liquid supplied to them. The following table sets forth the figures representing such results.

	Average percentage purification effected throughout the experiments, by the beds on the liquid supplied to them.
Series I. experiment—	
Coarse ragstone-bed	20·6
Fine ragstone-bed	35·9
Coarse coke-bed	22·5
Fine coke-bed	52·6
Series II. experiment—	
Primary coarse bed A	46·3
Secondary coarse bed A 1	31·9
Primary coarse bed B	47·0
Secondary fine bed B 1	52·1
Series III. experiment—	
Coarse coke-bed A	38·8
Fine coke-bed B	51·2

From these results it will be seen that the fine coke-bed in the last series of experiments dealing with settled sewage, effected a purification practically equal in amount to the best results obtained from any single bed in previous experiments. But it will be remembered that in the instances where the amount of purification effected by a single bed in previous experiments was

equal to that of the fine coke-bed B of the last experiment, the coke-beds were dealing with sewage which had received previous treatment in a primary coke-bed, whereas in the last experiment the coke-bed had been dealing with sewage which had been only imperfectly settled and which had been subjected to but very slight septic action.

In the case of the coarse coke-bed the amount of purification effected was greater in the last series of experiments than that effected by the secondary coarse-bed A 1 in the previous series of experiments. The result obtained by the coarse coke-bed A is hardly comparable with the results obtained by the primary coarse beds of Series I. and II., as the sewage supplied to them had not been treated in any way, whereas in Series III. the sewage had been previously subjected to sedimentation.

It will therefore be seen that the coke-beds used in the experiments of Series III. effected practically as much purification on a sewage which had been previously settled as the secondary coke-beds of Series I. and II. effected on a sewage which had been previously treated in primary coke-beds. But the advantage of the method of previous settlement and treatment in a single coke-bed, over that of primary and secondary treatment in coke-beds without previous settlement, is that in the former process the primary coke-beds are rapidly thrown out of action by loss of capacity by choking, while in the latter process the choking is avoided. The results of the experiments at the Council's Outfall Works and at other centres indicate that when the settlement of the sewage is conducted on a large scale, and is accompanied by energetic septic action, the coke-beds do not lose capacity at all by the accumulation in them of sewage sludge, but only by the growth of purifying bacteria upon the coke surfaces. This growth is necessary and desirable if it is kept, as it can be kept, within reasonable limits.

From November 7th, 1900, to January 27th, 1901, the samples of sewage supplied to the two settling tanks were mixed together before being analysed, as were also the samples of the settled sewage flowing from the two settling tanks to the coke-beds ; on and after January 28th these samples were all separately analysed.

III.—EXPERIMENTAL BACTERIAL TREATMENT OF CRUDE SEWAGE AT THE SOUTHERN OUTFALL WORKS (CROSSNESS).

1.—TABULATED LIST OF THE EXPERIMENTS AND OF THE BACTERIA-BEDS.

The various experiments at the Southern Outfall Works in connection with the bacterial or natural treatment of sewage are included in the following list.

The treatment of crude sewage in bacteria-beds, with or without previous settlement—

(*a*) Without previous settlement—

In a single coke-bed, from April 22nd, 1898, to February 22nd, 1899 (Series I.).

In primary and secondary beds in series from September 1st, 1898, to February 22nd, 1899 (Series I.).

In a single coke-bed 13 feet deep from February 27th, 1899, to October 10th, 1899 (Series II.).

(*b*) With previous settlement—

In a single coke-bed, 13 feet deep, from October 10th, 1899, to July 28th, 1900 (Series II.).

In a single coke-bed, with continuous flow, from November 20th, 1899, to May 26th, 1900 (Series II.).

In a single coke-bed, preceded by septic action, from November 1st, 1900, to October 5th, 1901 (Series III.).

The history of the three tanks which have been used throughout the experiments in the treatment of London sewage in coke-beds and in settling tanks at the Southern Outfall Works, is set forth in the following table—

	TANK A. 22 ft. 6 in. by 10 ft. 8 in., 13 ft. deep.	TANK B. 22 ft. 6 in. by 10 ft. 8 in., 13 ft. deep.	TANK C. 22 ft. 6 in. by 11 ft. 9 in. (average), 6 ft. deep.
1898 Apr. 22	... ...	4 ft. single bed.	
June 21	6 ft. secondary bed. (Used as a single bed at first in order to "mature" the coke.)		
July 12	... ...	... ...	6 ft. primary bed. (In course of construction, but dealing with sewage meanwhile.)
Sept. 1	In proper working order as a secondary bed.	... ...	Bed completed and in working order as a primary bed.
1899 Feb. 22		End of experiments of Series I.	
„ 27	13 ft. single bed. (Depth being increased from meanwhile.)	6 ft. to 13 ft., but bed working	
Apr. 11	13 ft. single bed. (In proper working order.)		
Oct. 10	End of experiment and commencement of experiment with sedimented sewage.		
Nov. 20	... ...	4 ft. single bed. (Continuous method.)	
Dec. 24 1900 Jan. 13	During this period the experi channels were being carried	ments on the sedimentation of r out. None of these coke beds	aw sewage in the large settling were then in use.
„ 15	13 ft. single bed. (Dealing with sedimented sewage and number of fillings per day increased.)		
July 28		End of experiments of Series II.	
Nov. 1	6 ft. single bed No. 2.	6 ft. single bed, No. 1.	Used as a settling tank and afterwards as a septic tank also.
1901 Oct. 5		End of experiments of Series III.	

2.—SUMMARY OF THE DETAILS, PREVIOUSLY REPORTED, OF THE EXPERIMENTAL BACTERIAL OR NATURAL TREATMENT OF SEWAGE AT THE SOUTHERN OUTFALL WORKS (CROSSNESS), WITH SUCH ADDITIONS AS ARE NECESSARY TO COMPLETE THE INFORMATION RESPECTING THE EXPERIMENTS.

(a) Treatment of Crude Sewage in a Single Coke-bed and in Primary and Secondary Coke-beds in Series (Series I.).

I.—*The Single Coke-bed.*

This bed was composed of coke fragments about the size of walnuts, and was made in tank B by filling it with the coke to a depth of 4 feet. The bed was underdrained by a series of parallel loose-jointed stoneware drain pipes. Its capacity was 3,000 gallons.

The bed was first charged with crude unsedimented sewage on April 22nd, 1898, and it continued to receive two fillings per day until June 23rd, 1898, except on Saturdays, when it received only one filling, and on Sundays, when it rested entirely. After a fortnight's rest, which was necessitated through overwork in its imperfectly "matured" condition, the bed received only one filling per day until November 7th, 1898, and from November 8th, 1898, to February 22nd, 1899, when this series of experiments was concluded, it received two fillings per day. During the whole period this bed was filled 345 times.

The average amount of purification effected on the crude sewage by this bed, as measured by the relative quantities of oxygen absorbed from permanganate by the dissolved putrescible matter in the crude sewage and in the coke-bed effluent, was 51·3 per cent.

II.—*The Primary and Secondary Coke-beds worked in series.*

The filling in of the primary bed of this series with coke occupied from July 12th to September 1st, 1898, but during that period it was frequently charged with sewage in order to avoid any delay in "maturing" it.

The secondary bed was also "matured" by treatment with sewage during its construction, but after it had been completed on June 21st, 1898, it had to be worked as a single coke-bed until September 1st, on which date the primary bed was completed. From that date these beds were worked in series until February 22nd, 1899.

From September 1st, 1898, to February 22nd, 1899, the beds were filled 219 times.

The average amount of purification effected on the crude sewage was 69·2 per cent. when measured, as in the foregoing case, by the removal of dissolved putrescible matter.

Full information respecting these beds was published in the Second Report on the "Bacterial Treatment of Crude Sewage."

(b) Treatment of Crude Sewage in a Coke-bed 13 feet deep. (Series II.)

This series of experiments was carried out in order to ascertain whether any variation in the purifying action was caused by increasing the depth of the coke-bed. With this object in view, the 6-foot secondary bed of the previous experiment was deepened to 13 feet and was then worked as a single bed. The coke fragments of which the bed was composed were of such a size as would pass a 2-inch mesh and be rejected by a 1-inch mesh.

On February 28th, 1899, the first addition was made to the bed, and its depth was increased to 7 feet 5 inches, but the full depth of 13 feet was not attained until April 11th, 1899. The bed was, however, worked while it was being deepened, so as to "mature" the new coke as rapidly as possible.

The history of the bed may be divided into three periods—

i. The bed received crude, unsettled sewage between February 27th, 1899, and October 9th, 1899. It was filled once a day from February 27th to March 25th, 1899, and generally twice a day from March 27th to October 9th, 1899, except on Saturdays, when it received only one filling, and on Sundays, when it rested entirely.

Its capacity diminished rapidly, as is shown by the following figures—

- March 9th, 1899, capacity 7,900 gallons or 41 per cent. of the empty tank capacity;
- June 8th, 1899, capacity 6,670 gallons or 35 per cent. of the empty tank capacity;
- October 10th, 1899, capacity 5,530 gallons or 29 per cent. of the empty tank capacity.

ii. The bed received very roughly sedimented sewage between October 13th, 1899, and April 5th, 1900, and was filled twice a day until December 22nd, 1899, and then three times a day until April 5th, 1900.

In consequence of the loss of capacity suffered by the bed when it was fed with crude sewage (Period I.), it was decided to allow the crude sewage to settle before it reached the bed. This was effected by pumping it into a large wooden tank placed on the top of the bed; the overflow from this tank passed on to the bed.

The capacity of the bed on January 12th, 1900, was 6,000 gallons or 32 per cent. of the empty tank capacity. The bed had been resting from December 22nd, 1899.

iii. The bed received sedimented sewage between May 3rd and July 28th, 1900, and it was filled generally four times a day.

The process of sedimentation consisted in allowing the crude sewage to flow through a tank on its way to the coke-bed. It entered this tank through a broad pipe, which descended nearly to the bottom, and was drawn off by a pipe, the end of which was immersed below the surface of the liquid. The passage through the tank occupied about five hours.

The capacity of the coke-bed on June 16th, 1900, was 6,000 gallons, after resting from April, 5th to May 2nd, 1900, and on October 8th, 1900, it was 6,290 gallons, after resting from 28th July, 1900.

In consequence of the bed having been altered before this last measurement was taken, its capacity was calculated on a measurement of only the lower 6 feet of the bed.

The process of filling this bed occupied from 20 to 25 minutes; it was allowed to remain full for two hours, and the process of emptying extended over from one hour to one hour and a half. The number of hours during which the bed rested between the successive emptyings and fillings varied according to the number of times it was filled during the 24 hours. When the number of fillings per day did not exceed two, the fillings were made during the daytime, but when the number of fillings exceeded two, they were distributed evenly over the whole 24 hours.

The following table indicates the average amount of purification which was effected by this bed during the different periods referred to above. Two purification averages have been calculated: one from the relative quantities of oxygen absorbed by the crude sewage and by the coke-bed effluent, from potassium permanganate by the total putrescible matter (both suspended and dissolved), and the other from the oxygen absorbed by the dissolved putrescible matter only—

	Percentage removal of total putrescible matter.	Percentage removal of dissolved putrescible matter.
I. From February 27th to October 9th, 1899 ...	—	48·1
II. From October 10th, 1899, to April 5th, 1900	57·2	54·6
III. From May 2nd, 1900, to July 28th, 1900 ...	56·6	55·7
From February 27th, 1899, to July 28th, 1900	57·0	51·8

Throughout the period during which the coke-bed was filled four times a day, the effluent from it was clear and free from odour.

While these experiments were in progress frequent analyses were made of the air in the interstices of the empty coke-bed at depths of 6 feet and 13 feet; the following results were obtained—

Six-foot depth.			Thirteen-foot depth.		
Number of hours since sewage drained off.	Percentage of oxygen in the air from the bed.	Percentage of carbonic acid in the air from the bed.	Number of hours since sewage drained off.	Percentage of oxygen in the air from the bed.	Percentage of carbonic acid in the air from the bed.
4	19·8	0·4	22	18·4	1·4
22	9·8	5·8	26·75	14·0	3·8
24·5	10·0	6·0	50·75	14·8	3·0
37	17·8	2·0	51·25	15·3	3·3
40·5	16·8	2·4	70	14·7	0·8

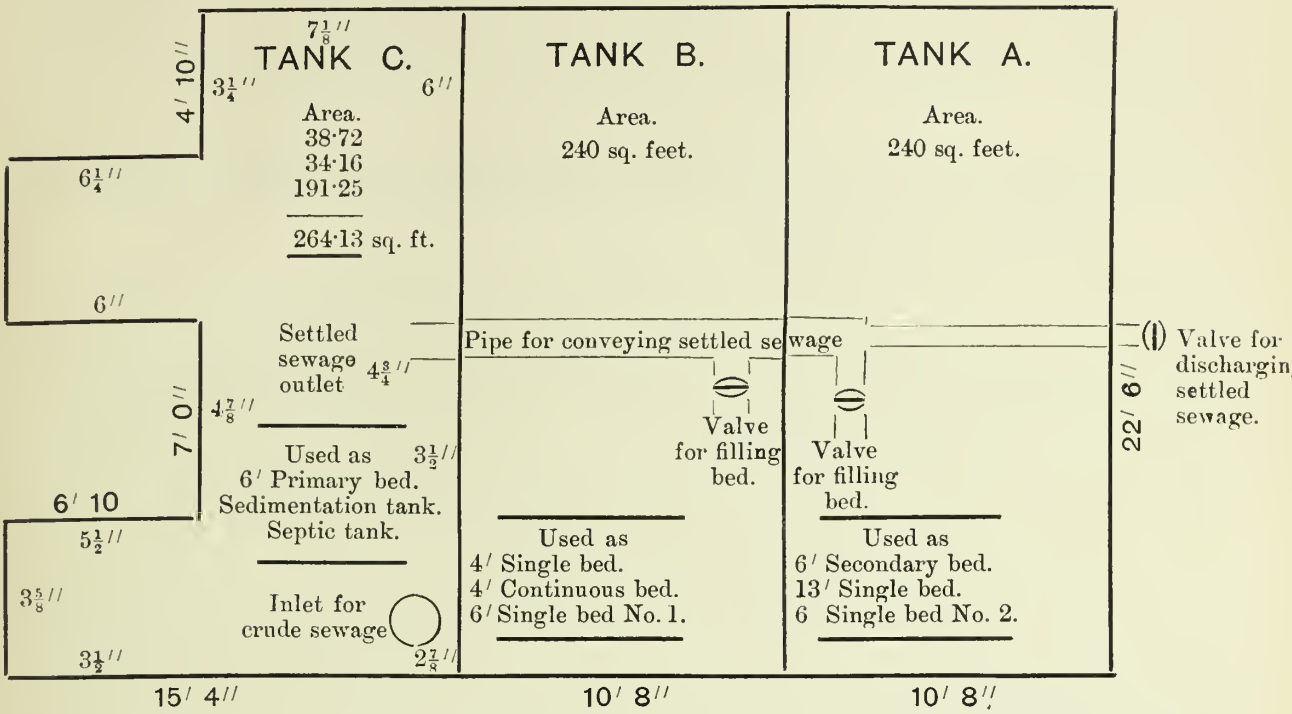
The results prove that, even in the case of the deep 13-foot bed, the air at the lower part of the bed was not seriously deficient in oxygen.

On June 20th, 1900, the depth of the sludge in the brick tank from which the 13-foot coke-bed was filled was between $2\frac{7}{8}$ inches at the inlet to the tank, to $7\frac{1}{8}$ inches at the further end of the tank, and $4\frac{3}{4}$ inches at the outlet from the tank to the coke-bed. This outlet was at about two-thirds of the distance from the inlet to the further end. The depth of the sludge in this tank at various points is indicated in the accompanying plan.

The average percentage of organic matter in the dried sludge from the tank was 35·8.

No permanent scum was formed on the liquid in the settling tank, and it was found that the effect produced by the bacteria in the settling tank was independent of the presence or absence of scum.

Plan of tanks used in connection with the bacterial or natural treatment of sewage.



The figures against the inside of the lines representing the sides of the tank C indicate the depth of sludge referred to on p. 18 (Series II.).

The figures against the outside of the lines of the plan indicate the dimensions of the tanks.

The pipe with the valves was used in connection with the experiments of Series III.

As a result of the whole series of experiments, it was proved that the crude sewage of London could not be satisfactorily dealt with in coke-beds unless it was subjected to a preliminary settling process; since, although the coke-beds deliver a satisfactorily purified effluent, they choke up very rapidly if they are constantly charged with crude, unsettled sewage.

Full details of the working of this bed were published in the Third Report on the "Bacterial Treatment of Crude Sewage" on pp. 14-16, and the details of the analytical results up to the end of 1899 appear on pp. 35-37. The averages of the analyses of the crude sewage and of the coke-bed effluent, given in this Report in table 6, p. 35, complete the publication of information respecting this series of experiments.

In the Second Report tanks A and B were stated to be 12 feet deep; this measurement was, however, only approximate, and in no way affected the experiments referred to in that Report. On making exact measurements of the depth of the tank for the purpose of this experiment, it was found that the depth was 13 feet. This measurement includes a coping which was not considered in the previous measurement.

(c) Experiments on the Rapid Sedimentation of Crude Sewage on a Large Scale and the Subsequent Treatment of a Portion of the Settled Sewage in a Small Coke-bed.

During three weeks, between December 24th, 1899, and January 13th, 1900, the coke-bed experiments, then in progress at the Southern Outfall Works at Crossness, were stopped in order to carry out a large scale experiment on the rapid sedimentation of the whole of the crude sewage received from South London and the subsequent treatment of a small portion of the sedimented sewage in a coke-bed. The sewage received at this Outfall underwent sedimentation in the settling channels, but was not treated with chemicals during the three weeks. It was allowed to flow more rapidly than usual through the channels; the rate of flow averaging 7·4 feet per minute, whilst the usual rate of flow of the chemically-treated sewage is 1·5 foot per minute.

Four channels, each of 6,000,000 gallons capacity, were used, and two of 3,000,000 gallons capacity each. Their length was 581 feet each.

A portion of this rapidly sedimented sewage was afterwards treated in a small coke-bed contained in a tank of 280 gallons capacity. The bed was filled three times a day. Its capacity remained constant during the experiments, and the bed suffered in no way from choking.

The amount of purification effected on the crude sewage by the sedimentation and by the bed was as follows—

By the rapid sedimentation in the settling channel—
  Purification from total putrescible matter, 16·1 per cent.
  Purification from dissolved putrescible matter, 0·4 per cent.
By the bacterial action of the coke-bed on the settled sewage—
  Purification from dissolved putrescible matter, 52·9 per cent.
By the combined action of the settling channel and of the coke-bed—
  Purification from dissolved putrescible matter, 58·7 per cent.

This experiment showed that rapidly settled sewage could be dealt with in coke-beds without reducing their capacity, and that this treatment yielded a satisfactory effluent. The period over which this experiment extended was too short to admit of septic action being set up in the settling channels ; but it seems reasonable to anticipate that if the rapid sedimentation were accompanied by septic action, a still greater amount of purification would be effected.

3. ADDITIONAL PARTICULARS OF THE EXPERIMENTS ON THE BACTERIAL OR NATURAL PROCESS OF SEWAGE PURIFICATION AT THE SOUTHERN OUT-FALL WORKS (CROSSNESS).

(*a*) Treatment of Settled Sewage by Continuous Feed through a Distributor to a four foot Coke-bed. (Series II.)

From November 20th, 1899, to May 26th, 1900, experiments were carried out with the continuous feeding of a coke-bed with settled sewage supplied through a distributor. For this purpose the 4-foot single bed in tank B was used, and various methods of continuously feeding the bed with settled sewage were adopted.

A decided decrease in the amount of purification of the settled raw sewage was apparent when a quantity of sewage equal to that dealt with on the intermittent principle was passed continuously through the bed. This decrease was probably due to—

(*a*) The overcharging of the bed with sewage.

(*b*) The reduction of the bacterial action owing to the chilling of the sewage by contact with the cold air during the winter time.

It appears desirable that the temperature of sewage should not fall below 53° Fahr. if the bacteria are to rapidly carry on their purifying action. This temperature is always exceeded when the sewage is supplied to the bed on the intermittent system.

The continuous feeding of the bed further appeared at times to have the effect of washing the useful deposit from the surfaces of the coke fragments.

The various methods of continuous feeding adopted during these experiments did not effect a satisfactory purification, and they did not deal with the sewage as rapidly as it was dealt with by the intermittent treatment.

(*b*) Treatment of Crude Sewage by Continuous Passage through a Settling Tank and by Subsequent Intermittent Passage through Coke-Beds. (Series III.)

These experiments were commenced on November 1st, 1900, and lasted until October 5th, 1901. They were undertaken with the view of supplementing the results obtained from the rough experiments (Series II.) on the septic treatment of sewage, which had lasted from May 3rd to July 28th, 1900.

I.—*Particulars as to the Construction of the Tanks and of the Coke-beds.*

Tank C, which had been previously used as a 6-foot primary coke-bed, was emptied of the coke and was used as a settling and septic tank for the crude sewage before it underwent treatment in the coke-beds. Tank B, which had been used as a 4-foot single coke-bed, was increased in depth to 6 feet with coke fragments which passed through a 2-inch mesh and which were rejected by a 1-inch mesh. This bed was called the 6-foot single bed No. 1. Tank A was filled to a depth of 6 feet with coke fragments similar in size to those forming bed No. 1. This bed was called the 6-foot single bed No. 2. It had previously contained 13 feet of coke, and the 6-foot bed was simply formed by removing sufficient coke to leave a bed of 6 feet in depth.

Both beds were underdrained with loosely jointed earthenware agricultural drain-pipes.

The capacity of the septic tank was 9,000 gallons, but the actual quantity of liquid in the tank varied somewhat during the working.

II.—*Method of working the Tank and Beds.*

For the purpose of measuring the quantity of sewage which was supplied to the settling and septic tank, a meter was fixed to the delivery pipe which conveyed the crude sewage to the septic tank.

From the settling tank an outlet-pipe conveyed the settled sewage to either No. 1 or No. 2 coke-bed, or when the coke-beds were not being filled, to the main effluent discharge culvert.

At first the settled sewage was supplied to the beds by allowing it to overflow from wooden troughs, but this method was afterwards replaced by one in which the liquid fell from the distributing pipes into perforated wooden trays placed upon the surface of the beds.

The filling of each bed occupied about half an hour ; the bed remained full for two hours and occupied one hour in emptying. The resting period varied with the number of fillings per 24 hours.

The crude sewage samples for analysis were taken at the inlet to the tank, and the settled sewage samples were taken at the outlet.

The arrangement of the tanks is shown in the diagram on p. 19. It should, however, be borne in mind that the bottom of tank C was on the same level as the top of tanks A and B.

III.—*As to the Number of Times the Coke-beds were filled.*

The coke-beds were filled four times a day until the middle of January, 1901 (see table VII., p. 36). From January 14th to 21st, 1901, No. 1 bed was supplied with settled sewage on

the continuous principle; from the latter date until April 15th both beds were thrown out of use, first on account of lime water from the chemical treatment of the sewage at this Outfall having gained access to the beds, and afterwards by the choking of the suction pipe of the pump supplying the settling tank with crude sewage. Owing to a change in the pumping arrangements which was made in March, it was impossible to give the settling tank a continuous supply of sewage, and it was also impossible to always fill the beds four times each day.

The other days during the specified period on which the coke-beds were not filled were either Sundays, when they never were in use ; Saturdays, when the height of the sewage in the main was not sufficient during the morning to work the pump; public holidays and the first week in August, which latter was fixed as the time for the annual holiday of the coke-bed samplers.

IV.—*As to the Capacity of the Coke-beds.*

The original capacity of the wet coke-beds was not estimated, since in the case of both beds the coke had been previously in use.

The measurement of October 8th, 1900 (table VII., p. 36), of coke-bed No. 2 was made when the 13-foot bed of the previous experiments had been reduced to 6 feet. It may, therefore, be accepted as the capacity of the bed previous to starting this series of experiments, as it had been draining since July 28th, 1900, and could hardly be expected to appreciably increase in capacity during the 23 days before the first filling of this series took place.

On examining the other figures representing the capacity at various times, it will be observed that the capacity of coke-bed No. 2 gradually decreased while the bed was receiving four fillings per day, but that after it had rested for six weeks its capacity greatly increased; it again diminished, however, immediately after the resting period, and ultimately remained for about six months with a fairly constant capacity. This second decrease in capacity, as would be expected, was slower than before the rest, on account of the reduced number of fillings per day which the bed received.

The ease with which the capacity of the coke-bed No. 2 was increased by a short rest indicates that its loss of capacity was mainly due to accumulated organic or putrescible matter in the bed ; this would no doubt be largely avoided by more perfect previous sedimentation of the sewage and by more energetic septic action, both of which conditions would be fulfilled when larger settling channels were used.

V.—*Relative to the Action of the Settling or Septic Tank.*

On January 18th, 1901, the septic tank was roughly covered over, and as a result the liquid in it became coated with a thick scum, which, on January 28th, was about one inch thick. This scum continued to grow thicker, and to increase in toughness, especially after the tank had been closed. The bacterial action appeared to have increased, since gas was evolved in larger quantity ; but the solution of organic matter was not more marked than before the cover was placed over the tank.

The usual method of working the septic tank was to allow a unit volume of sewage about six hours to pass through the tank. This was about equal to the average time which a unit volume of sewage takes to pass through the large settling channels in the chemical and sedimentation process.

The solution of organic matter continued, but on February 27th, 1901, the pump feeding the septic tank became choked with sludge, owing to the stoppage of the main pumps at the east end of the engine house for alterations, and the experimental work had to be stopped. The pipe in connection with the pump which took the sewage from the main sewers at the Outfall Works was, therefore, shortened by about 5 feet, in order to prevent choking in the future, and as a consequence of this shortening of the pipe the end of it was often above the level of the sewage in the mains. It was, therefore, only when the level of the sewage rose to a certain height that the feed pipe of the pump was in the liquid, and that the pump could be used for filling the septic tank. The alteration in the pumping arrangements consequently prevented the septic tank from receiving in future a continuous feed of crude sewage.

On February 27th, 1901, the scum on the top of the liquid in the septic tank had entirely disappeared.

On March 28th, 1901, an examination of the septic tank was made, when it was found that 25·6 per cent. of the sediment or sludge had been liquefied by bacterial action. During the whole period that the tank had been in action, 41·2 per cent. of the sludge disappeared. The great difference in the percentage reduction of sludge in the tank during the period November 1st, 1900, to March 28th, 1901, and the period November 1st, 1900, to October 5th, 1901, is probably due to—

(*a*) The efficiency of the septic tank increasing with the length of time during which it had been in use, since the sludge was not cleared out of the tank at the end of the first period.

(*b*) The fact that during the first period the sewage was supplied to the tank almost uninterruptedly, whereas during the period March 29th, 1901, to October 5th, 1901, the sewage supply to the septic tank was by no means continuous, owing to alterations in the pumping arrangements.

The weekly average quantities of crude sewage which passed through the septic tank were—

From November 1st, 1900, to March 28th, 1901, 131,817 gallons, or 21,969 gallons per day.

From March 29th, 1901, to October 5th, 1901, 89,898 gallons, or 14,983 gallons per day.

By reference to Table X. it will be seen that during the whole period from November 1st, 1901, to October 5th, 1901, the septic action in the settling tank reduced the amount of solid matter deposited therein by 41·2 per cent. This deposited solid matter consisted of—

(*a*) *Mineral matter*, principally sand, grit and mineral road detritus which *are not* affected by the septic action, and which, when working on a large scale, would to a great extent be separated, by previous sedimentation, from the other constituent of the deposited solids.

(*b*) *Organic matter*, comprising, in addition to fæcal matter, husks of cereals, chips of wood, paper, etc., which latter *are* only acted upon by the bacteria in the septic tank with extreme slowness.

A much more accurate idea of the action which occurred in the septic tank is obtainable, therefore, when the reduction of the solid matter is calculated as a percentage of the total solid organic matter deposited in the tank. By reference to Table X. it will be seen that this amounted to 71·4 per cent.

With respect to the figures given in Table X., the following particulars may be useful—

(*a*) The figures representing the quantity of crude sewage supplied to the tank are obtained by calculation from the quantities indicated in the meter which was fixed to the inlet pipe.

(*b*) The sludge left in the tank at the end of the first period (column 2) was not removed before the second period commenced, but was left in the tank to mix with the sludge which was deposited during the second period. It is noteworthy that the sludge finally obtained contained less liquid than the former quantity since it had been more fully drained.

(*c*) The averages of the amounts of suspended matter in the crude sewage and in the settled sewage are the averages of the daily estimations made during the time over which the experiments extended. The average amount of solid matter in the sludge is the result of an estimation which was made after the sludge had been well mixed in the tank in order to obtain an average sample.

(*d*) The proportions of the mineral and organic constituents of the suspended matter in the sewage have been calculated on the basis of—

41·6 per cent. of mineral matter and 58·4 per cent. of organic matter in the suspended solids in the crude sewage,

40·9 per cent. of mineral matter and 59·1 per cent. of organic matter in the settled sewage.

These percentages were obtained from the averages of the daily estimations which were made on the crude and on the settled sewage during the three weeks' experiment from December 24th, 1899, to January 13th, 1900.

These components of the suspended solids were not estimated during the experiments lasting from November 1st, 1900, to October 5th, 1901.

(*e*) The figures under the heading "Calculated quantity of sludge left in the Tank" are the differences between the amounts of suspended matter found in the crude sewage and in the settled sewage.

(*f*) The calculated quantity of sludge left in the tank is the quantity which would have been found in the settling tank if no septic action had taken place. The difference between this quantity and that actually found, is the quantity of solid matter which was liquefied by the action of the bacteria in the settling tank.

(*g*) The figures representing the proportions of the mineral and of the organic constituents of the solids in the sludge were obtained by direct estimation made on a portion of the sludge itself.

VI.—*As to the Action of the Coke-beds.*

Monthly and general averages of the various chemical estimations made on the crude sewage, on the settled sewage, and on the coke-bed effluent are set forth in Tables VIII. and IX.

From these tables it will be seen that the average amount of purification effected on the crude sewage throughout the whole of the experiments, by the combined action of the settling tank and of the coke-beds, was 58·7 per cent. when measured by the amount of total putrescible matter (both suspended and dissolved) removed, and 55·7 per cent. when measured by the removal of the dissolved putrescible matter only.

The figures representing the estimations made of the effluents from the two coke-beds will be found to agree very well with each other except in the case of the estimations of nitric nitrogen. The divergence under this heading, however, is not so great as to necessitate any inquiry as to the cause of the difference, since the difference is well within the ordinary variations to which coke-beds are liable in this respect.

VII.—*As to the Putrescibility of the Crude Sewage, of the Settled Sewage of the Chemical Effluent and of the Coke-bed Effluent.*

During this series of experiments the putrescibility of the crude sewage, of the settled sewage, of the effluent from the chemically treated and sedimented sewage, and of the effluent from the coke-beds was tested at the Southern Outfall Works. The observations and estimations made in this connection are set forth in Table XI.

The methods adopted in making these tests depended on—

(*a*) The estimation of the amount of oxygen absorbed from permanganate in three minutes at 80° Fahr. by the putrescible matter in the various liquids at the time of the collection of the samples, and the repetition of the estimation after they had been kept for a period of seven days in an incubator at 80° Fahr.

(*b*) The examination of the liquids, after seven days' incubation at 80° Fahr., as to visible signs of putrescence, as to the presence of sulphuretted hydrogen, and as to their offensive nature.

It will be seen that the increase in the amount of oxygen absorbed by the liquids after incubation for seven days, as compared with the amount absorbed at the time of collection, was 100 per cent. greater in the case of the effluent from the chemically treated and sedimented sewage than it was in the case of the coke-bed effluent. In addition to this comparison it will be observed that out of 10 samples of the coke-bed effluent, 8 were not putrescible, and the other 2, if putrescible, were so only to a very small extent, as the indications were of a very indefinite nature ; also the 10 samples were free from sulphuretted hydrogen, whereas, in the case of the 15 samples of crude sewage, of settled sewage and of chemical effluent they were all putrescible and black in appearance, and 14 of them contained sulphuretted hydrogen, and the other sample was very foul.

From these observations it is evident that the coke-bed effluent, when compared with the effluent from the chemically treated and sedimented sewage, is one that would abstract from the river water a much smaller amount of its dissolved oxygen than that which is abstracted by the effluent at present discharged into the river. It would also, if discharged into the river, impart to the water no offensive colour or odour, either at first or at any later stage.

VIII.—*As to the Extent to which the Liquid Capacity of a Coke-bed is affected by the Size of the Coke Fragments, by the Length of Time during which the Coke has been soaking, and by the Draining Period of the Bed.*

In the Third Report on the Bacterial Treatment of Crude Sewage the results were given of tests as to the capacity of coke-beds composed of coke of different sizes. The results of the tests tended to show that as the shape of the particles of the materials of which a coke-bed was formed, departed from the spherical form the capacity of a coke-bed became more directly proportional to the size of the fragments of the material of which it was composed.

Experiments were conducted during February and March, 1900, to ascertain the variations in the capacity of a coke-bed arising from the length of time during which the material composing the bed had been soaking and by the length of time during which it had been draining.

The coke-bed used for this purpose was composed of fragments of coke of such a size as would pass a ½-inch mesh, and they were contained in an iron tank of 280 gallons capacity.

The following figures indicate the results obtained—

Date.	Capacity as indicated by meter.	Capacity as indicated by standard measure.	Particulars as to the condition of the coke.
1900.			
21st February ...	150	—	Coke new and dry.
27th „ ...	127	—	Coke soaking from February 23rd.
4th March ...	97	—	„ „ „ 28th.
13th „ ...	140	—	„ „ March 6th.
14th „ ...	132	135	Drained for 2 hours.
15th „ ...	136	144	„ 16 „
16th „ ...	137	144	„ 17 „

IV.—TABULATION OF THE RESULTS OF THE CHEMICAL EXAMINATION OF THE CRUDE SEWAGE AND OF THE EFFLUENTS.

In previous Reports the figures representing the results of the analyses of the various liquids have been given for each day during the time which the Reports covered. This was found to necessitate the insertion of so large a mass of figures that it has been discontinued, and in the present Report monthly averages only are submitted. The space thus saved has admitted of the insertion of other tables, without unduly increasing the mass of figures.

All figures representing the results of analytical estimations are given in parts per 100,000, unless otherwise stated.

(To convert parts per 100,000 into grains per gallon, multiply by 0·7; to convert grains per gallon into parts per 100,000, multiply by $\frac{10}{7}$.)

The following explanation of the headings of the columns in the various tables may be found useful—

Oxygen absorbed from permanganate in four hours at 80° Fahr.

(*a*) By the crude liquid (total putrescible matter).

The figures in this column represent the amount of oxygen which the crude liquid absorbed from potassium permanganate in four hours when kept in a constant temperature chamber at 80° Fahr. The figures are to some extent a measure of the putrescibility of the liquid, since the oxygen is absorbed by oxidisable matter dissolved in the liquid and floating in the liquid as minute solid particles (total putrescible matter). When sewage is discharged into sea-water it absorbs three times as much of the dissolved oxygen as it absorbs from permanganate, and it would thus very seriously reduce the aëration of the water. (See Report of the Royal Commission on Sewage Disposal, vol. ii., Dr. Letts' evidence, p. 479.)

(*b*) By the clear liquid (dissolved putrescible matter).

These figures are obtained in a similar manner to those in the column headed "By the crude liquid." The only difference is that the estimations are made in the clear liquid produced by passing the turbid liquid through ordinary filter paper; whereas, in the case of the crude liquid estimations, the liquid is dealt with in the unfiltered state.

Nitric and nitrous nitrogen.

The figures in these columns represent the amount of nitrogen which was found to be present in the form of nitrite and of nitrate. These compounds are produced in the liquid by the oxidising action of nitrifying bacteria in the coke-bed. They indicate, to some extent, the amount of oxidation and purification which has taken place. Nitrates are fully oxidised products and nitrites are only partially oxidised products. Both bodies are produced in sewage effluents by the oxidation of nitrogenous compounds present in the sewage. Their presence and permanence indicate that purification of the sewage has taken place, since they cannot exist in impure liquids, as such liquids lead to their deoxidation and destruction. It has been shown that the presence of nitrates in an effluent may prevent the putrefaction of a certain amount of organic substances from occurring in another effluent with which the nitrate effluent has been mixed.

Table I.—Averages of Figures relating to the Treatment of Sewage Effluent in the One-acre Coke-bed at the Northern Outfall Works.

This table gives the monthly averages of the daily estimations of the amount of oxygen absorbed from permanganate by the crude liquids (total putrescible matter) and by the clear liquids (dissolved putrescible matter). The liquids dealt with were—(*a*) The sewage as it arrived at the works and before treatment of any kind; (*b*) the effluent from the chemically treated and sedimented sewage as it was supplied to the coke-bed; (*c*) the effluent from the coke-bed. The table also contains the monthly averages of the daily estimations of the quantity of nitrous and nitric nitrogen in the liquid supplied to the coke-bed and in the effluent from the bed. It should be noted that the averages of the crude sewage were calculated from the results of the daily analysis of a sample of sewage which was obtained by mixing together samples of equal volume collected every hour throughout the twenty-four hours, whereas, the samples of the "chemical" effluent and of the coke-bed effluent, which were taken for analysis, corresponded with only a portion of the day's sewage. It will therefore be seen that the figures for the crude sewage are not strictly comparable with the figures for the "chemical" effluent and for the coke-bed effluent, although any error likely to arise from this cause is minimised by the averages extending over long periods.

No estimations were made of the nitrous and nitric nitrogen in the sewage, since nitrogen in these conditions is more often absent than present, and even when present its quantity is usually too small to be worthy of consideration.

The records of the analyses of the "chemical" effluent supplied to this bed and of the coke-bed effluent, extending from May 12th, 1898 (the date of the commencement of the experiments after the bed had been deepened to 6 feet), to December 31st, 1899, were published on pp. 25 to 34 of the Third Report on the Bacterial Treatment of Sewage.

Table II.—Averages of the Figures relating to the Treatment of Crude Sewage in Double Coke-beds at the Northern Outfall Works. (Series II.)

The figures appearing in this table which relate to time previous to 1900 are averages of the figures which were published in the Third Report. The periods over which the different averages extend have been determined by the number of fillings of the coke-bed per day or per week. These were as follows—

One filling per day: July 4th to 15th, 1899.
Three fillings per week: July 17th to September 18th, 1899.
One filling per day: September 21st to December 9th, 1899.
Two fillings per day: December 11th to 15th, 1899.

Table III.—Treatment of Crude Sewage in a Settling-tank and in a Coarse and in a Fine Coke-bed at the Northern Outfall Works. Record of the Number of Times the Coke-beds were filled per Day and of the Capacity of the Beds. (Series III).

The period during which the beds were allowed to drain before their capacities were taken depended upon the number of fillings per day. Generally, when the beds received only one filling each day, the drainage period was twenty-one hours, with two fillings per day the drainage period was nine hours, and with three fillings per day it was five hours. It has already been stated that these differences in the drainage periods did not materially affect the capacity results.

Tables IV. and V.—Averages of the Figures relating to the rapid Sedimentation and subsequent Bacterial Treatment of Crude Sewage in a Coarse Coke-bed and in a Fine Coke-bed at the Northern Outfall Works. (Series III.)

In this series of experiments the crude sewage and the settled sewage during November and December, 1900, and part of January, 1901, were not separately sampled for the two sets of settling tanks and beds, hence the figures relating to the crude sewage for the first two months are the same for each set. After December, 1900, separate samples were taken of the sewage which was supplied to each bed.

In these experiments the whole of the settled sewage passed through the coke-beds, therefore, there is only one set of figures relating to the settled sewage. In the corresponding experiments at Crossness the settled sewage was allowed to run to waste when the coke-beds were standing fully charged, consequently the average settled sewage obtained from the settling tank was not necessarily similar to the average of that supplied to the beds.

Table VI.—Averages of the Figures relating to the Treatment of Crude Sewage in Coke-beds at the Southern Outfall Works. (Series II.)

This table gives the monthly averages of the daily examination of the crude sewage as supplied to the 4-foot coke-bed, which was worked on the continuous method of feeding, and of the effluent from the bed. Although this bed was at work during part of the year 1899 the results of the work were not given in the Third Report on the Bacterial Treatment of Sewage, because the work had only been in progress for a few months, and no final results had been obtained.

The other part of this table gives averages of the figures obtained by the chemical analysis of the crude sewage supplied to the 13-foot coke-bed working on the intermittent method, and of the effluent from the bed. The daily analytical figures relating to this bed up to the end of 1899 were published in the Third Report, but in order to bring the whole of the results into one table, averages for three periods during 1899 have been included in this table, together with monthly averages of the results obtained during 1900.

Table VII.—Treatment of Crude Sewage in a Settling Tank and in Coke-beds at the Southern Outfall Works. Record of the Number of Times the Coke-beds were Filled per Day, and of the Capacity of the Beds (Series III.)

The figures given in this table refer to experiments of Series III. at the Southern Outfall Works. On those days which are not included in this list, the coke-beds were not in use, as is explained on p. 21. Only one measurement was made of the capacity of bed No. 1, namely, on January 9th, 1900.

The percentage capacities of the coke-beds given in this table are percentages of the capacity of that portion of the tank which is filled with the coke-bed, assuming that portion to contain no coke.

Table VIII.—Averages of the Figures relating to the rapid Sedimentation of Crude Sewage at the Southern Outfall Works. (Series III.)

This table gives the monthly averages of the whole of the figures relating to the chemical analysis of the crude sewage as supplied to the settling and septic tank used in connection with the experiments of Series III., and of the settled sewage from the settling tank.

Table IX.—Averages of the Figures relating to the Treatment of rapidly Sedimented Sewage in Coke-beds at the Southern Outfall Works. (Series III.)

This table gives the monthly averages of the whole of the figures relating to the chemical analysis of the portion of the settled sewage from the settling and septic tank which was supplied to the coke-beds used in connection with the experiments of Series III., and of the effluents from the coke-beds.

Table X.—Particulars as to the Disappearance of Sludge in the Settling Tank at the Southern Outfall Works. (Series III.)

The data given in this table are derived from actual estimations. They are given for the purpose of indicating the manner in which the figures representing the amount of solid matter liquefied in the septic tank have been obtained. Full details of the various figures will be found on p. 22 of this report.

Table XI.—Results of the Incubation at 80°F. of Settled Sewage, of "Chemical" Effluent and of Coke-bed Effluent at the Southern Outfall Works. (Series III.)

This table gives the analytical details and the results of the examination of samples of settled sewage, of "chemical" effluent and of coke-bed effluent which had been kept in an incubator for seven days.

Table XII.—Average percentage purification effected by the Chemical Treatment and subsequent Sedimentation of the Sewage, by the Settling Tanks used in connection with Coke-beds and by the Various Coke-beds at the Outfall Works.

The purification is calculated from the relative quantities of oxygen absorbed from permanganate by the liquid, both before and after treatment. The two sets of figures represent the percentage removal of total putrescible matter (the crude liquid), and of dissolved putrescible matter (the clear liquid). Except in the case of the figures representing the purification effected by the chemical treatment and subsequent sedimentation, each set of figures represents the actual purification effected only by the individual tank or bed. Any purification effected on the liquid previous to or subsequent to that effected by the tank or bed in question has not been considered in the calculations.

The figures in this table indicate the amount of purification effected by each single bed on the liquid with which it dealt. No preliminary treatment of the liquid before it was supplied to the bed has been taken into account. The percentages merely measure the value of the work performed by each bed. Figures representing the average percentage purification effected by the chemical treatment and subsequent sedimentation during the years 1900 and 1901 are added for the sake of comparison.

Table XIII.—Average percentage purification of the Crude Sewage effected by the Various Methods of Experimental Bacterial Treatment and by the "Chemical Treatment" carried out at the Outfall Works.

The amount of purification effected is calculated from the figures representing the amount of oxygen absorbed from permanganate by the crude sewage and by the final effluents from each treatment.

Whereas the preceding table affords an opportunity of comparing the amount of work performed by each coke-bed on the liquid with which it dealt, this table sets forth the amount of purification effected on the crude sewage by the tanks and coke-beds used in the various experiments at both Outfall Works. The amount of purification recorded in this table is that which was effected by the whole process of each experiment. The figures have been calculated from the relative amounts of oxygen absorbed from permanganate by the crude liquid and by the clear liquid of both the raw sewage and the final effluent.

IV.—TABULATION OF THE RESULTS OF THE CHEMICAL EXAMINATION OF THE CRUDE SEWAGE, OF THE "CHEMICAL" EFFLUENT, AND OF THE VARIOUS COKE-BED EFFLUENTS.

IV.—TABULATION OF THE RESULTS OF THE CHEMICAL EXAMINATION VARIOUS COKE-

I.—BARKING

TABLE I.—AVERAGES OF FIGURES RELATING TO THE TREATMENT OF SEWAGE

All quantities, except where otherwise stated,

Date.	Average daily crude sewage. Oxygen absorbed from permanganate in 4 hours at 80° F. By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)	Effluent from the chemically treated and sedimented sewage as supplied to the coke-bed ("chemical" effluent). Oxygen absorbed from permanganate in 4 hours at 80° F. By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)	Nitrous nitrogen.	Nitric nitrogen.
1900.						
January	11·145	5·526	6·629	4·957	0·0555	0·1430
February...	11·009	5·299	6·735	5·134	0·1271	0·0907
March	11·910	6·658	7·526	6·074	0·0567	0·0936
April	12·072	6·552	7·781	6·409	0·0181	0·0234
May	12·123	6·239	6·678	5·022	Nil	Nil
June	11·441	4·940	6·018	4·355	0·0022	0·0030
July	10·848	4·663	6·136	4·203	Nil	0·0235
August	10·989	4·719	7·019	3·974	Nil	0·0970
September	11·384	5·014	6·997	5·106	Nil	Nil
October	11·382	5·247	7·377	5·942	0·0004	0·0377
November	12·056	5·766	7·417	6·175	0·0015	Nil
December	12·281	5·908	7·989	6·650	0·0276	0·0935
Average for the year	11·546	5·543	7·015	5·344	0·0245	0·0504
1901.						
January	12·440	6·579	8·010	6·785	0·0367	0·1020
February...	13·036	7·511	7·350	6·242	0·0358	0·1506
March	12·684	6·557	7·760	6·573	0·0563	0·0755
April	11·865	5·992	7·705	6·278	0·0230	0·0054
May	11·745	5·898	7·366	5·927	0·0036	0·0090
June	11·651	5·393	7·166	5·456	Nil	Nil
July	10·897	4·780	5·847	4·248	0·0081	Nil
August	10·578	4·501	5·921	3·965	Nil	Nil
September	10·577	4·516	6·337	4·336	Nil	Nil
October	11·703	5·615	7·431	5·376	0·0023	Nil
November	12·135	6·282	7·732	5·841	0·0098	0·0154
December	12·219	6·351	7·911	6·410	0·0456	0·0523
Average for the year	11·793	5·825	7·219	5·649	0·0186	0·0346

Average percentage purification effected on the "chemical" effluent by the bacterial treatment during 1900
" " " " ... 1901
" " " " 1900–1

Average percentage purification effected on the crude sewage by the chemical and bacterial treatments combined during 1900
" " " " ... 1901
" " " " 1900–1

OF THE CRUDE SEWAGE, OF THE "CHEMICAL" EFFLUENT, AND OF THE BED EFFLUENTS.

RESULTS.

EFFLUENT IN THE ONE-ACRE COKE-BED AT THE NORTHERN OUTFALL WORKS.

are expressed in parts per 100,000.

Effluent from the coke-bed.				Quantity of effluent from the chemically treated and sedimented sewage which was passed on to the coke-bed per month.	Number of times the coke-bed was filled per month.	Average quantity of effluent which was passed on to the bed each time of filling.
Oxygen absorbed from permanganate in 4 hours at 80° F.		Nitrous nitrogen.	Nitric nitrogen.			
By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)			Gallons.		
0·890	0·723	0·0330	0·7605	23,356,361	52	449,161
0·898	0·753	0·0362	1·0868	18,400,442	46	400,010
0·998	0·866	0·0352	1·0071	18,354,936	52	352,980
1·086	0·934	0·0439	1·2021	14,391,847	42	342,663
0·972	0·840	0·0444	0·9490	17,015,411	52	327,219
0·939	0·760	0·0542	0·9053	13,792,523	43	320,756
0·999	0·792	0·0501	0·6007	16,002,669	50	320,053
1·010	0·808	0·0502	0·8458	12,168,147	38	320,214
1·029	0·840	0·0991	1·2353	15,823,348	46	343,986
1·019	0·848	0·0691	1·3078	18,044,051	52	347,001
1·131	0·979	0·0743	1·3023	16,025,918	46	348,390
1·083	0·942	0·0608	1·3347	15,630,440	44	355,237
1·003	0·840	0·0541	1·0429	199,006,093	563	353,474
1·023	0·919	0·0626	1·1776	18,413,046	52	354,097
1·161	1·055	0·0872	1·3095	16,121,827	46	350,474
1·126	1·039	0·0701	1·3298	16,924,070	50	338,481
1·123	1·011	0·1004	1·1117	15,481,724	46	336,559
1·158	1·029	0·1176	0·6283	16,558,407	50	331,168
1·161	1·010	0·1016	0·7862	16,012,550	48	333,595
1·021	0·856	0·0718	0·7253	16,889,950	51	331,175
1·009	0·845	0·0710	0·6797	15,972,684	48	332,764
0·914	0·790	0·0637	1·0986	11,751,012	35	335,743
0·910	0·790	0·0685	0·6663	14,976,516	45	332,811
0·952	0·821	0·0525	0·8259	16,405,221	50	328,104
0·973	0·861	0·0741	1·1641	14,612,640	44	332,105
1·045	0·920	0·0782	0·9513	190,119,647	565	336,495
85·7	84·3					
85·5	83·7					
85·6	84·0					
91·3	84·9					
91·1	84·2					
91·2	84·5					

Table II.—Averages of the Figures relating to the Treatment of Crude Sewage in Double Coke-beds at the Northern Outfall Works. (Series II.)

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date.	Solids in suspension.	Oxygen absorbed from permanganate in 4 hours at 80° Fah. By crude liquid. (Total putrescible matter.)	Oxygen absorbed from permanganate in 4 hours at 80° Fah. By clear liquid. (Dissolved putrescible matter.)	Nitrous nitrogen.	Nitric nitrogen.
	Crude sewage as supplied to the coke-beds.				
1899.					
July 4 to 15 ...	...	...	6·003	Nil	0·1628
July 17 to September 18 ...	...	...	6·028	Nil	0·2290
September 21 to December 9...	71·6	11·218	6·157	0·0082	0·2495
December 11 to 31 ...	69·6	11·114	6·533	0·0933	0·1878
1900.					
January ...	63·2	12·091	5·787	0·0152	0·1194
February ...	68·0	12·160	5·625	0·1064	0·0782
March ...	56·4	12·936	6·721	0·0312	0·1181
April ...	71·8	13·477	7·044	0·0016	0·0120
May ...	74·6	13·100	6·400	Nil	Nil
Average for 1900 ...	65·0	12·711	6·328	0·0291	0·0783
Average for the whole period ...	67·6	12·118	6·237	0·0162	0·1617
	Effluent from primary coarse bed A.				
1899.					
July 4 to 15 ...	...	...	4·048	Nil	0·1784
July 17 to September 18 ...	...	...	3·382	0·1911	0·5962
September 21 to December 9...	13·3	5·236	3·367	0·1444	0·8071
December 11 to 31 ...	16·2	5·743	3·590	0·0720	0·3520
1900.					
January ...	15·3	5·389	3·175	0·0536	0·2905
February ...	13·6	4·780	2·810	0·1986	0·5985
March ...	16·8	5·744	3·276	0·0750	0·4082
April ...	20·2	7·144	3·600	0·0263	0·3648
May ...	27·0	7·420	3·020	0·0400	0·3708
Average for 1900 ...	17·7	5·957	3·213	0·0747	0·3937
Average for the whole period ...	16·1	5·726	3·349	0·1069	0·5291
	Effluent from secondary coarse bed A.				
1899.					
July 4 to 15 ...	...	...	2·473	Nil	0·1817
July 17 to September 18 ...	...	...	2·271	0·1648	1·4117
September 21 to December 9...	6·7	3·493	2·241	0·1018	1·6362
December 11 to 31 ...	8·7	3·867	2·543	0·1153	0·6695
1900.					
January ...	6·0	3·631	2·145	0·1264	0·7369
February ...	7·6	3·008	1·802	0·0871	1·3569
March ...	7·2	3·600	2·248	0·0828	1·1788
April ...	7·8	4·422	2·644	0·1461	0·9112
May ...	8·2	3·960	2·360	0·1840	1·1397
Average for 1900 ...	7·2	3·718	2·241	0·1187	1·0325
Average for the whole period ...	7·2	3·667	2·279	0·1137	1·1948
Average percentage purification of the crude sewage during the whole period ...	89·4	69·7	63·5	...	...

TABLE II.—(*continued*).

Date.	Solids in suspension.	Oxygen absorbed from permanganate in 4 hours at 80° Fah. By crude liquid. (Total putrescible matter.)	Oxygen absorbed from permanganate in 4 hours at 80° Fah. By clear liquid. (Dissolved putrescible matter.)	Nitrous nitrogen.	Nitric nitrogen.
	Effluent from primary coarse bed B.				
1899.					
July 4 to 15	...	...	3·886	Nil	1·8470
July 17 to September 18	...	...	3·407	0·0647	0·5005
September 21 to December 9...	13·8	5·334	3·369	0·1294	0·6125
December 11 to 31	20·2	5·610	3·667	0·0520	0·3180
1900.					
January...	14·4	5·259	3·018	0·0496	0·2884
February	14·0	4·780	2·625	0·0764	0·3135
March	10·8	5·728	3·248	0·0858	0·3424
April	13·2	6·500	3·400	0·0376	0·3264
May	13·4	5·640	3·120	0·0220	0·4255
Average for 1900	13·0	5·597	3·107	0·0582	0·3297
Average for the whole period ...	13·9	5·522	3·303	0·0769	0·4289
	Effluent from secondary fine bed B.				
1899.					
July 4 to 15	...	...	1·019	0·2374	1·7681
July 17 to September 18	...	...	1·259	0·0376	2·3568
September 21 to December 9...	3·2	1·773	1·474	0·0401	2·4583
December 11 to 31	3·6	2·552	2·114	0·0507	1·6514
1900.					
January...	5·8	2·208	1·676	0·0508	2·1327
February	2·6	1·830	1·419	0·0429	2·7167
March	0·8	2·384	1·784	0·0518	2·1371
April	2·8	2·644	2·055	0·0739	2·0999
May	2·4	2·280	1·540	0·0470	2·3668
Average for 1900	3·0	2·292	1·726	0·0540	2·2430
Average for the whole period ...	3·1	2·166	1·583	0·0564	2·2557
Average percentage purification of the crude sewage during the whole period	95·4	82·1	74·6	...	...

Table III.—Treatment of Crude Sewage in a Settling-tank and in a Coarse and in a Fine Coke-bed at the Northern Outfall Works. Record of the Number of Times the Coke-beds were Filled per Day and of the Capacity of the Beds. (Series III.)

Date.	Number of fillings each day of		Capacity of	
	Bed A.	Bed B.	Bed A (coarse).	Bed B (fine).
1900.				
Nov. 8	1	1	41·7	40·3
,, 9	2	2		
,, 10	2	2		
,, 12 to Nov. 14 ...	3	3		
,, 15 ,, 19 ...	1	1		
,, 20	1	1	38·5	38·5
,, 21 ,, 26 ...	1	1		
,, 27	1	1	38·8	38·8
,, 28 to Dec. 3 ...	1	1		
Dec. 4	1	1	38·5	37·5
,, 6 ,, 8 ...	1	1		
,, 11	2	2	37·8	37·8
,, 12 ,, 15 ...	2	2		
,, 17	2	2		
,, 18	2	2	36·1	35·4
,, 19 and 20 ...	2	2		
,, 21	1	1		
,, 22	1	1		
,, 27	1	1		
,, 28 to Dec. 31 ..	2	2		
1901.				
Jan. 1	2	2	35·3	33·3
,, 2 and 3 ...	2	2		
,, 4	1	1		
,, 11 to Jan. 14 ...	2	2		
,, 15	2	2	34·7	32·6
,, 16 ,, 19 ...	2	2		
,, 21 and 22 ...	2	2		
,, 23	2	2	34·7	31·2
,, 24 and 25 ...	2	2		
,, 28	–	2		
,, 29	1	2		
,, 30	2	2	35·4	30·6
,, 31	2	2		
Feb. 1	1	1		
,, 2 to Feb. 4 ...	2	2		
,, 5	2	2	32·7	29·2
,, 6	2	1		
,, 7	2	–		
,, 8	1	–		
,, 9 and 11 ...	2	2		
,, 12	1	–		
,, 13	–	1		
,, 18	–	1		
,, 19	1	2		
,, 20	2	2	33·3	29·2
,, 22 to Mar. 11 ...	2	2		

Date.	Number of fillings each day of		Capacity of	
	Bed A.	Bed B.	Bed A (coarse).	Bed B (fine).
1901.				
Mar. 12	2	2	32·0	26·7
,, 13 to Mar. 20 ...	2	2		
,, 21	2	2	32·7	25·3
,, 22 and 23 ...	2	2		
,, 25	3	3		
,, 26	1	–		
,, 27	2	1		
,, 28	1	–		
,, 29	2	1		
Apl. 1 to Apl. 3 ...	2	2		
,, 10	2	2		
,, 11 ,, 15 ...	3	3		
,, 16	3	3	31·2	21·2
,, 17 ,, 19 ...	3	3		
,, 20	2	2		
,, 22	3	3		
,, 23	2	2		
May 6 and 7	1	1		
,, 8 to May 10 ...	2	2		
,, 13	1	1		
,, 14 ,, 15 ...	2	2		
,, 17	2	2	31·5	25·0
,, 18 ,, 24 ...	2	2		
,, 29 to June 3 ...	2	2		
June 4	2	2	32·2	25·0
,, 5	1	2		
,, 6 ,, 10 ...	–	2		
,, 11 and 12 ...	–	1		
,, 13 to June 17 ...	–	2		
,, 18	–	2		22·9
,, 19 and 20 ...	–	2		
,, 21	–	1		
,, 25 to June 27 ...	–	1		
,, 28 to July 1 ...	1	1		
July 2	1	1	34·0	22·2
,, 3	2	2		
,, 4 ,, 11 ...	1	1		
,, 17 ,, 22 ...	1	1		
,, 23	1	1	34·0	24·3
,, 24 ,, 29 ...	1	1		
,, 30	1	1	33·3	25·3
,, 31 to Aug. 2 ...	1	1		
Aug. 6	1	1		
Total number of fillings	287	313		

Table IV.—Averages of the Figures relating to the rapid Sedimentation and subsequent Bacterial Treatment of Crude Sewage in a Coarse Coke-bed at the Northern Outfall Works. (Series III.)

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date.	Solids in suspension.	Oxygen absorbed from permanganate in 4 hours at 80° F. By crude liquid. (Total putrescible matter.)	Oxygen absorbed from permanganate in 4 hours at 80° F. By clear liquid. (Dissolved putrescible matter.)	Nitrous nitrogen.	Nitric nitrogen.
	Crude sewage as supplied to the settling tank A.				
1900.					
November	65·9	14·028	7·940	0·0020	0·0042
December	76·1	13·418	7·118	0·0086	Nil
Average for 1900 ...	71·3	13·708	7·509	0·0055	0·0020
1901.					
January	73·3	13·573	7·429	0·0143	·0333
February	77·7	13·500	7·756	0·0283	·2197
March	69·4	13·106	7·237	0·0145	·0700
April	50·3	11·273	5·908	0 0353	·0374
May	58·7	12·521	6·380	Nil	Nil
June	54·0	12·487	5·891	Nil	Nil
July	60·2	11·725	5·495	0·0013	Nil
August	60·7	13·659	6·339	Nil	Nil
Average for 1901 ...	64·9	12·680	6·676	0·0134	0·0540
Average for the whole period	66·5	12·933	6·882	0·0115	0·0412
	Settled sewage as supplied to coke-bed A.				
1900.					
November	15·4	8·410	6·026	0·0021	0·1123
December	15·6	8·000	5·655	0·0023	0·2824
Average for 1900 ...	15·5	8·190	5·827	0·0022	0·2036
1901.					
January	17·0	8·983	5·856	0·0056	0·3780
February	14·5	8·389	6·167	0·0101	0·3673
March	16·0	7·956	5·881	0·0022	0·1795
April	18·1	7·073	4·596	Nil	0·0910
May	10·8	7·845	5·120	Nil	0·0094
June	29·2	11·131	6·016	Nil	Nil
July	27·4	9·829	4·159	0·0013	Nil
August	32·7	10·195	3·724	Nil	Nil
Average for 1901 ...	18·4	8·492	5·299	0·0030	0·1578
Average for the whole period	17·7	8·419	5·427	0·0022	0·1689
	Effluent from coke-bed A.				
1900.					
November	11·9	5·638	3·981	0·0687	0·8685
December	9·1	5·064	3·418	0·0360	0·8425
Average for 1900 ...	10·4	5·330	3·679	0·0512	0·8546
1901.					
January	10·2	5·605	3·605	0·0286	0·8525
February	9·3	5·506	3·500	0·0678	0·6844
March	9·3	4·891	3·248	0·0331	0·5157
April	11·3	4·452	2·901	0·0133	0·2416
May	7·8	4·557	3·068	0·0258	0·4396
June	22·0	8·367	4·635	0·0220	1·7951
July	9·2	4·525	2·681	0·0230	1·1078
August	7·3	3·528	2·418	0·0100	1·1347
Average for 1901 ...	9·9	5·026	3·205	0·0311	0·7197
Average for the whole period	10·0	5·100	3·320	0·0360	0·7524
Average percentage purification of the crude sewage during the whole period	85·0	60·6	51·8	—	—

Table V.—Averages of the Figures relating to the rapid Sedimentation and subsequent Bacterial Treatment of Crude Sewage in a Fine Coke-bed at the Northern Outfall Works. (Series III.)

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date.	Solids in suspension.	Oxygen absorbed from permanganate in 4 hours at 80° Fahr. By crude liquid. (Total putrescible matter.)	Oxygen absorbed from permanganate in 4 hours at 80° Fahr. By clear liquid. (Dissolved putrescible matter.)	Nitrous Nitrogen.	Nitric Nitrogen.
	Crude sewage as supplied to the settling tank B.				
1900.					
November	65·9	14·028	7·940	0·0020	0·0042
December	76·1	13·418	7·118	0·0086	Nil
Average for 1900 ...	71·3	13·702	7·509	0·0055	0·0020
1901.					
January	73·4	13·459	7·279	0·0119	0·0411
February	71·3	13·244	7·267	0·0422	0·1658
March	70·3	12·862	7·100	0·0118	0·0861
April...	54·0	11·166	5·711	0·0297	0·0121
May	64·9	12·679	6·170	Nil	Nil
June	59·9	12·529	5·700	Nil	Nil
July	63·7	11·690	5·462	0·0013	Nil
August	70·7	13·659	6·993	Nil	Nil
Average for 1901 ...	65·8	12·574	6·397	0·0121	0·0414
Average for the whole period	67·0	12·829	6·648	0·0106	0·0326
	Settled sewage as supplied to coke-bed B.				
1900.					
November	15·4	8·410	6·026	0·0021	0·1123
December	15·6	8·000	5·655	0·0023	0·2824
Average for 1900 ...	15·5	8·190	5·827	0·0022	0·2036
1901.					
January	16·4	8·252	5·695	Nil	0·3750
February	14·0	8·529	6·318	0·0139	0·2232
March	12·4	7·666	5·693	0·0026	0·1321
April	11·6	7·192	4·757	Nil	0·0302
May	6·4	7·419	5·028	Nil	0·0473
June	8·4	8·224	5·034	Nil	Nil
July	22·0	9·829	4·252	0·0013	Nil
August	16·7	9·411	3·594	Nil	Nil
Average for 1901 ...	13·5	8·248	5·203	0·0023	0·1115
Average for the whole period	13·9	8·235	5·341	0·0022	0·1319
	Effluent from coke-bed B.				
1900.					
November	4·0	3·801	3·096	0·0537	2·144
December	3·0	3·609	2·891	0·0196	1·824
Average for 1900 ...	3·5	3·698	2·986	0·0354	1·972
1901.					
January	3·3	3·659	2·976	0·0274	1·2485
February	2·2	3·471	2·800	0·0789	0·1223
March	1·2	3·253	2·792	0·0440	1·0389
April...	3·9	2·942	2·358	0·1416	0·8064
May	2·5	2·860	2·398	0·0890	1·7668
June	4·6	3·688	2·328	0·0722	0·2372
July	4·0	2·996	1·991	0·0222	1·3551
August	4·7	2·417	1·568	0·0433	1·7209
Average for 1901 ...	3·1	3·262	2·495	0·0628	1·0997
Average for the whole period	3·2	3·358	2·604	0·0567	1·2931
Average percentage purification of the crude sewage during the whole period	95·2	73·8	60·8	—	—

II.—CROSSNESS RESULTS.

TABLE VI.—AVERAGES OF THE FIGURES RELATING TO THE TREATMENT OF CRUDE SEWAGE IN COKE-BEDS AT THE SOUTHERN OUTFALL WORKS. (SERIES II.).

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date.	Oxygen absorbed from permanganate in 4 hours at 80° Fah.		Nitrous nitrogen.	Nitric nitrogen.	Oxygen absorbed from permanganate in 4 hours at 80° Fah.		Nitrous nitrogen.	Nitric nitrogen.
	By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)			By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)		
	Continuous treatment. Crude sewage as supplied to the 4-foot coke bed.				*Continuous treatment. Effluent from the 4-foot coke-bed.*			
1899.								
November...	7·122	4·696	0·0050	0·0209	2·980	2·110	0·1216	0·1857
December	7·149	5·736	Nil	Nil	4·444	3·117	0·0156	0·0914
1900.								
January	4·610	3·587	0·0124	0·1125	2·782	1·546	0·1216	1·0008
February	6·042	4·794	0·0700	0·0944	3·818	2·170	0·1701	0·3544
March	5·070	4·035	0·0161	0·0054	2·827	2·115	0·0567	0·0768
April	5·698	4·408	0·0105	0·0477	3·703	2·356	0·1167	0·1586
May	4·922	3·715	Nil	Nil	3·087	2·066	0·0177	0·0284
Average for the whole period	5·708	4·376	0·0124	0·0343	3·379	2·234	0·0781	0·2262
Average percentage purification of the crude sewage	...	...	...	...	40·8	48·9	...	...
	Intermittent treatment. Settled sewage as supplied to the 13-foot coke-bed.				*Intermittent treatment. Effluent from the 13-foot coke-bed.*			
1899.								
February 27–March 25 ...	...	4·856	0·0026	Nil	...	2·268	0·0270	0·0693
March 27–October 9 ...	...	4·826	0·0034	0·0023	...	2·546	0·0355	0·1673
October 13–December 22	10·110	6·522	0·0044	0·0048	3·748	2·753	0·0540	0·1778
1900.								
January	7·096	5·195	0·0867	0·1667	3·146	2·204	0·1249	1·0861
February	7·050	5·158	0·1050	0·1549	3·390	2·576	0·1595	4·4163
March	7·334	5·632	0·0241	0·0056	3·519	2·755	0·0244	0·0997
April	9·128	6·849	Nil	Nil	4·667	3·391	Nil	0·0191
May	5·480	4·047	Nil	Nil	2·560	1·744	0·0342	0·0520
June	5·378	3·944	Nil	Nil	2·427	1·896	0·0023	0·0146
July	5·484	3·709	Nil	Nil	2·092	1·559	0·0117	0·0074
Average for 1900 ...	6·328	4·644	0·0300	0·0426	2·885	2·150	0·0511	0·2197
Average for the whole period	7·159	4·962	0·0141	0·0186	3·075	2·394	0·0434	0·1829
Average percentage purification of the crude sewage	...	...	...	...	57·0	51·8	...	...

TABLE VII.—TREATMENT OF CRUDE SEWAGE IN A SETTLING-TANK AND IN COKE-BEDS AT THE SOUTHERN OUTFALL WORKS. RECORD OF THE NUMBER OF TIMES THE COKE-BEDS WERE FILLED PER DAY, AND OF THE CAPACITY OF THE BEDS. (SERIES III.)

Date.	Number of fillings per day.		Capacity of beds.			
	Bed No. 1.	Bed No. 2.	Bed No. 1.		Bed No. 2.	
			Gallons.	Percentage of empty tank.	Gallons.	Percentage of empty tank.
(Capacity of empty tank at a depth of 6 feet)			9,000		9,000	
(Estimated original capacity)			4,500	50	4,500	50
1900.						
Oct. 8 ...	(Bed resting from July 28, 1900)				2,900	32·2
Nov. 1 to 3 ...	4	4				
,, 5 ...	4	4			2,750	30·6
,, 6 to 22 ...	4	4				
,, 26 to Dec. 5 ...	4	4				
Dec. 6 ...	4	4			2,550	28·4
,, 7 to 22 ...	4	4				
1901.						
Dec. 27 to Jan. 8 ...	4	4				
Jan. 9 ...	4	4	2,130	23·7	2,150	23·9
,, 10 ...	4	4				
,, 14 to 19 ...	continuous	4				
,, 21 ...	,,	4			2,100	23·3
March 7 ...	—	—			2,600	28·9
April 15 ...	2	2				
,, 16 ...	1	1				
,, 17 ...	2	2				
,, 18 ...	3	3				
,, 19 ...	2	2				
,, 20 ...	1	1				
,, 22 ...	3	3				
,, 23 ...	2	2				
,, 24 and 25 ...	3	3				
,, 26 ...	4	4				
,, 29 ...	2	2				
,, 30 ...	3	3				
May 1 ...	3	3			2,475	27·5
,, 2 and 3 ...	2	2				
,, 6, 7 ...	2	2				
,, 8 ...	3	3				
,, 9, 10 ...	4	4				
,, 11 ...	1	1				
,, 13 ...	2	2				
,, 14, 15 ...	4	3				
,, 16 ...	3	3				
,, 17 ...	4	4				
,, 20 to 23 ...	3	3				
,, 24 ...	2	2				
,, 29 to 31 ...	2	2				
June 3 to 6 ...	2	2				
,, 7 ...	1	1				
,, 10 ...	1	1				
,, 11 ...	2	2				
,, 12 ...	2	2			2,300	25·5
,, 13 ...	3	3				
,, 14 ...	2	2				
,, 17 to 21 ...	2	2				
,, 22 ...	1	1				
,, 24 to 28 ...	3	3				
,, 29 ...	1	1				
July 1 ...	3	3				
,, 2, 3 ...	4	4				
,, 4, 5 ...	3	3				
,, 6 ...	1	1				
,, 8 to 10 ...	3	3				

Date.	Number of fillings per day.		Capacity of beds.			
	Bed No. 1.	Bed No. 2.	Bed No. 1.		Bed No. 2.	
			Gallons.	Percentage of empty tank.	Gallons.	Percentage of empty tank.
1901.						
July 11 ...	4	4				
,, 12 ...	3	3				
,, 13 ...	1	1				
,, 15 ...	2	2				
,, 16 ...	3	3				
,, 17 ...	2	2				
,, 18 ...	4	4				
,, 19 ...	3	3				
,, 22 ...	3	3				
,, 23, 24 ...	2	2				
,, 25 ...	3	3				
,, 26 ...	4	4				
,, 27 ...	1	1				
,, 29 to Aug. 2 ...	3	3				
Aug. 12 ...	2	2				
,, 13 ...	2	3				
,, 14 ...	3	2				
,, 15 ...	4	4				
,, 16 ...	3	3				
,, 19 ...	1	1				
,, 20 ...	2	2				
,, 21 ...	3	3			2,200	24·4
,, 22 ...	3	3				
,, 23 ...	4	4				
,, 24 ...	1	1				
,, 26 to 30 ...	3	3				
Sept. 2 to 4 ...	3	3				
,, 5, 6 ...	2	2				
,, 9 to 11 ...	2	2				
,, 13 ...	1	1				
,, 16 ...	2	2				
,, 17 ...	4	4				
,, 18 ...	2	2				
,, 19, 20 ...	3	3				
,, 21 ...	1	1				
,, 23 ...	2	2				
,, 24 ...	4	4				
,, 25 ...	2	2				
,, 26 ...	1	1				
,, 27 ...	2	2				
,, 30 ...	2	2				
Oct. 1 to 4 ...	3	3				
,, 5 ...	—	—			2,175	24·2

TABLE VIII.—AVERAGES OF THE FIGURES RELATING TO THE RAPID SEDIMENTATION OF CRUDE SEWAGE AT THE SOUTHERN OUTFALL WORKS. (SERIES III.)

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date.	Solids in suspension.	Oxygen absorbed from permanganate in 4 hours at 80° Fahr.		Nitrous nitrogen	Nitric nitrogen.	Solids in suspension.	Oxygen absorbed from permanganate in 4 hours at 80° Fahr.		Nitrous nitrogen.	Nitric nitrogen.
		By the crude sewage. (Total putrescible matter.)	By the clear sewage. (Dissolved putrescible matter.)				By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)		
	Crude sewage as supplied to settling-tank.					*Effluent from settling-tank.*				
1900.										
November...	26·9	5·337	4·124	Nil	Nil	12·4	4·726	3·913	Nil	Nil
December	22·0	4·871	4·066	Nil	Nil	10·8	4·470	3·995	Nil	Nil
Average for 1900 ...	24·3	5·088	4·093	Nil	Nil	11·5	4·589	3·957	Nil	Nil
1901.										
January	27·0	4·907	4·060	0·0015	Nil	14·4	4·288	3·868	0·0121	Nil
February	37·1	6·583	4·241	0·0033	Nil	12·0	5·439	4·411	0·0162	0·0029
March	...	...	...	...	...	...	...	...	...	...
April	14·9	6·554	4·619	Nil	Nil	10·8	6·160	4·617	Nil	Nil
May	23·1	6·630	4·685	Nil	Nil	14·3	6·199	4·750	Nil	Nil
June	34·2	7·944	4·562	Nil	Nil	17·9	6·809	4·730	Nil	Nil
July	28·8	6·539	3·918	Nil	Nil	14·5	5·469	3·997	Nil	Nil
August	23·8	5·118	3·236	Nil	Nil	12·8	4·517	3·373	Nil	Nil
September	20·4	5·099	3·517	Nil	Nil	23·1	4·521	3·455	Nil	Nil
October	28·5	5·080	3·442	Nil	Nil	17·7	4·655	3·697	Nil	Nil
Average for 1901 ...	27·0	6·142	4·087	0·0006	Nil	14·1	5·377	4·133	0·0038	0·0004
Average for the whole period	26·5	5·936	4·088	0·0005	Nil	13·6	5·223	4·098	0·0031	0·0003
Average percentage purification of the crude sewage during the whole period ...						48·7	12·0	−0·24		

TABLE IX.—AVERAGES OF THE FIGURES RELATING TO THE TREATMENT OF RAPIDLY SEDIMENTED SEWAGE IN COKE-BEDS AT THE SOUTHERN OUTFALL WORKS. (SERIES III.)

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date.	Oxygen absorbed from permanganate in 4 hours at 80° Fahr.		Nitrous nitrogen.	Nitric nitrogen.	Oxygen absorbed from permanganate in 4 hours at 80° Fahr.		Nitrous nitrogen.	Nitric nitrogen.
	By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)			By the crude liquid. (Total putrescible matter.)	By the clear liquid. (Dissolved putrescible matter.)		
	Effluent from rapidly sedimented sewage as supplied to No. 1 coke-bed.				*Effluent from rapidly sedimented sewage as supplied to No. 2 coke-bed.*			
1900.								
November	4·993	3·673	Nil	Nil	4·881	3·710	Nil	Nil
December...	4·472	3·664	0·0013	Nil	4·519	3·618	0·0010	0·0029
Average for 1900 ...	4·715	3·668	0·0007	Nil	4·688	3·661	0·0006	0·0016
1901.								
January	4·596	4·021	0·0041	Nil	4·625	3·956	0·0025	0·0058
February	...	...	...	...	...	...	...	...
March	...	...	...	...	...	...	...	...
April	6·106	4·375	Nil	Nil	6·058	4·385	0·0037	Nil
May	6·192	4·223	Nil	Nil	6·169	4·394	Nil	Nil
June	6·548	4·151	0·0011	Nil	6·438	4·276	Nil	Nil
July	5·350	3·599	Nil	Nil	5·274	3·603	0·0009	Nil
August	4·776	3·220	Nil	Nil	4·590	3·243	0·0011	Nil
September	4·519	3·382	0·0008	Nil	4·593	3·274	0·0017	Nil
October	4·264	3·025	Nil	Nil	4·586	3·213	Nil	Nil
Average for 1901 ...	5·430	3·802	0·0007	Nil	5·390	3·835	0·0012	0·0006
Average for the whole period	5·263	3·771	0·0007	Nil	5·232	3·794	0·0010	0·0008
	Effluent from No. 1 coke-bed.				*Effluent from No. 2 coke-bed.*			
1900.								
November	2·592	1·987	0·0044	0·0253	2·505	1·930	0·0258	0·1168
December...	2·052	1·683	0·0412	0·0770	2·048	1·643	0·0256	0·0586
Average for 1900 ...	2·303	1·825	0·0251	0·0543	2·261	1·776	0·0257	0·0841
1901.								
January	3·412	2·916	0·0469	0·0696	3·052	2·600	0·0472	0·0971
February	...	...	...	...	...	...	...	...
March	...	...	...	...	...	...	...	...
April	3·144	2·407	0·2177	0·1215	3·202	2·420	0·1809	0·1576
May	2·688	1·970	0·0765	0·0261	2·852	2·136	0·0784	0·0539
June	2·678	1·764	0·0843	0·0389	2·925	2·037	0·0767	0·0330
July	1·922	1·405	0·0691	0·0340	1·917	1·411	0·0757	0·0393
August	2·165	1·547	0·0527	0·0403	2·052	1·513	0·0403	0·0466
September	2·144	1·672	0·0964	0·0417	2·217	1·635	0·0121	0·0862
October	1·700	1·336	0·2270	0·0462	1·736	1·400	0·2145	0·0640
Average for 1901 ...	2·489	1·858	0·0904	0·0477	2·516	1·887	0·0892	0·0663
Average for the whole period	2·445	1·850	0·0757	0·0492	2·456	1·861	0·0749	0·0703
Average percentage purification of the crude sewage during the whole period.	58·8	54·7	...	...	58·6	56·8	...	...

Table X.—Particulars as to the Disappearance of Sludge in the Settling-tank at the Southern Outfall Works. (Series III.)

1	During the period from November 1st, 1900, to March 28th, 1901. 2	During the period from March 29th, 1901, to October 5th, 1901. 3	During the whole period from November 1st, 1900, to October 5th, 1901. 4
Crude Sewage.			
Quantity of crude sewage supplied to the settling tank ... gallons	2,768,160	2,427,250	5,195,410
Average amount of suspended solids in the crude sewage ... parts per 100,000	28·1	25·3	...
Average amount of suspended solids in the crude sewage ... grains per gallon	19·7	17·7	...
Weight of suspended solids supplied to the tank ... Mineral constituents of solids ... lbs.	3,241	2,553	5,794
Weight of suspended solids supplied to the tank ... Organic constituents of solids ... lbs.	4,549	3,584	8,133
Weight of suspended solids supplied to the tank ... Total solids ... ... lbs.	7,790	6,137	13,927
Settled Sewage.			
Quantity of settled sewage which passed out of the settling tank gallons	2,765,548	2,427,593	5,193,142
Average amount of suspended solids in the settled sewage ... parts per 100,000	12·5	14·3	...
Average amount of suspended solids in the settled sewage ... grains per gallon	8·8	10·0	...
Weight of suspended solids which passed out of the tank Mineral constituents of solids ... lbs.	1,406	1,418	2,824
Weight of suspended solids which passed out of the tank Organic constituents of solids ... lbs.	2,031	2,050	4,081
Weight of suspended solids which passed out of the tank Total solids ... ... lbs.	3,437	3,468	6,905
Sludge.			
Actual quantity of sludge found in the tank ... ... gallons	2,612	2,269	2,269
Average amount of suspended solids in the sludge found in the tank ... ... percentage	...	...	16·4
Weight of suspended solids in the sludge found in the tank Mineral constituents of solids ... lbs.	...	...	2,808
Weight of suspended solids in the sludge found in the tank Organic constituents of solids ... lbs.	...	...	1,322
Weight of suspended solids in the sludge found in the tank Total solids ... ... lbs.	3,240	...	4,130
Calculated quantity of sludge left in the tank	...	...	...
Average amount of suspended solids removed from the sewage and left in the tank ... ... parts per 100,000	15·6	11·0	...
Average amount of suspended solids removed from the sewage and left in the tank ... ... grains per gallon	10·9	7·7	...
Weight of suspended solids in the sludge left in the tank Mineral constituents of solids ... lbs.	1,835	1,135	2,970
Weight of suspended solids in the sludge left in the tank Organic constituents of solids ... lbs.	2,518	1,534	4,052
Weight of suspended solids in the sludge left in the tank Total solids ... ... lbs.	4,353	2,669	7,022
Quantity of sludge (organic matter only) which disappeared by the septic action in the tank ... ... lbs.	1,113	...	2,892
Percentage quantity of sludge which disappeared, calculated on total solids	25·6	...	41·2
Percentage quantity of sludge which disappeared, calculated on organic constituents	...	...	71·4

TABLE XI.—RESULTS OF THE INCUBATION AT 80° F. OF SETTLED SEWAGE, OF "CHEMICAL" EFFLUENT, AND OF COKE-BED EFFLUENT AT THE SOUTHERN OUTFALL WORKS. (SERIES III.)

All quantities, except where otherwise stated, are expressed in parts per 100,000.

Date	Settled sewage as supplied to No. 1 coke-bed.			Settled sewage as supplied to No. 2 coke-bed.			Effluent from the chemically treated and sedimented sewage.			Effluent from No. 1 coke-bed.			Effluent from No. 2 coke-bed.		
	Oxygen absorbed from permanganate in 3 minutes at 80° Fah.		As to whether the liquid was putrescible or not.	Oxygen absorbed from permanganate in 3 minutes at 80° Fah.		As to whether the liquid was putrescible or not.	Oxygen absorbed from permanganate in 3 minutes at 80° Fah.		As to whether the liquid was putrescible or not.	Oxygen absorbed from permanganate in 3 minutes at 80° Fah.		As to whether the liquid was putrescible or not.	Oxygen absorbed from permanganate in 3 minutes at 80° Fah.		As to whether the liquid was putrescible or not.
	At once.	After incubation for 7 days.		At once.	After incubation for 7 days.		At once.	After incubation for 7 days.		At once.	After incubation for 7 days.		At once.	After incubation for 7 days.	
1900.															
Dec. 11 ...	1·905	6·250	Yes	2·285	6·538	Yes	3·524	8·077	Yes	0·857	0·481	No	0·857	0·673	No
,, 12 ...	3·029	8·835	Yes	3·029	9·709	Yes	3·509	8·738	Yes	1·154	1·651	?	1·058	1·359	No
,, 13 ...	3·725	11·250	Yes	4·020	11·731	Yes	3·431	7·404	Yes	1 078	1·731	?	1·274	1·442	No
,, 14 ...	3·204	8·654	Yes	3·398	8·461	Yes	3·498	6·827	Yes	1·262	1·250	No	1·262	1·346	No
,, 15 ...	2·913	8·270	Yes	3·010	8·942	Yes	3·689	7·308	Yes	1·165	1·346	No	1·262	1·250	No
Average	2·955	8·652		3·148	9·076		3·530	7·671		1·103	1·292		1·143	1·214	
Percentage increase ...	—	192·8		—	188·3		—	117·3		—	17·1		—	6·2	

Appearance of the liquid after incubation for seven days.

Date	Settled sewage as supplied to No. 1 coke-bed.	Settled sewage as supplied to No. 2 coke-bed.	Effluent from the chemically treated and sedimented sewage.	Effluent from No. 1 coke-bed.	Effluent from No. 2 coke-bed.
Dec. 11 ...	Black. Strong H_2S ...	Black. Strong H_2S ...	Black. Very strong H_2S ...	Clear and bright. No odour.	Yellow colour. Earthy odour.
,, 12 ...	Black. Much H_2S	Black. H_2S	Black. Very foul	Yellow. Faint earthy odour	Clear. No odour.
,, 13 ...	Black. H_2S	Black. H_2S	Black. Much H_2S	Dark. Faint odour... ...	Darkish. No odour.
,, 14 ...	Black. H_2S	Black. H_2S	Black. Small quantity H_2S	Clear. No odour	Clear. No odour.
,, 15 ...	Black. H_2S	Black. H_2S	Black. H_2S	No odour	No odour.

TABLE XII.—AVERAGE PERCENTAGE PURIFICATION EFFECTED BY THE CHEMICAL TREATMENT AND SUBSEQUENT SEDIMENTATION OF THE SEWAGE, BY THE SETTLING TANKS USED IN CONNECTION WITH COKE-BEDS AND BY THE VARIOUS COKE-BEDS AT THE OUTFALL WORKS.

The purification is calculated from the relative quantities of oxygen absorbed from permanganate by the liquid, both before and after treatment. The two sets of figures represent the percentage removal of total putrescible matter (the crude liquid) and of dissolved putrescible matter (the clear liquid). Except in the case of the figures representing the purification effected by the chemical treatment and subsequent sedimentation, each set of figures represents the actual purification effected only by the individual tank or bed. Any purification effected on the liquid previous to or subsequent to that effected by the tank or bed in question has not been considered in the calculations.

	One or less number of fillings of the bed per day.		Two fillings of the bed per day.		Three fillings of the bed per day.		Four fillings of the bed per day.		During the whole experiment.	
	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.
Northern Outfall.										
The one-acre coke-bed ("chemical" effluent), 1900 and 1901	...	...	85·6	84·0	...	...	...	...	85·6	84·0
Series I.—										
Primary coarse ragstone-bed (crude sewage)	...	20·2	...	21·0	...	...	...	...	...	20·6
Primary coarse coke-bed (crude sewage) ...	...	22·3	...	22·6	...	...	...	...	...	22·5
Secondary fine ragstone-bed (second contact)	...	33·3	...	38·7	...	...	...	...	...	35·9
Secondary fine coke-bed (second contact) ...	...	54·7	...	50·2	...	...	...	...	...	52·6
Series II.—										
Primary coarse coke-bed A (crude sewage) ...	53·3	43·7	52·5	48·9	...	...	...	...	52·7	46·3
Primary coarse coke-bed B (crude sewage)...	52·5	43·8	55·2	50·2	...	...	...	...	54·8	47·0
Secondary coarse coke-bed A (second contact)	33·3	33·9	36·9	30·0	...	...	...	...	36·0	31·9
Secondary fine coke-bed B (second contact)	66·8	60·1	58·4	44·1	...	...	...	...	60·8	52·1
Series III.—										
Single coarse coke-bed A (settled sewage) ...	...	...	...	...	...	...	...	...	39·4	38·8
Single fine coke-bed B (settled sewage) ...	...	...	...	...	...	...	...	...	59·0	51·2
Chemical treatment and sedimentation 1900 ...	...	...	...	...	...	...	...	...	32·8	Nil
Chemical treatment and sedimentation 1901 ...	...	...	...	...	...	...	...	...	25·8	Nil
Southern Outfall.										
Series I.—										
4-foot single coke-bed (crude sewage) ...	...	...	...	...	...	...	...	...	...	52·8
6-foot primary coke-bed (crude sewage) ...	...	...	...	...	...	...	...	...	...	49·9
6-foot secondary coke-bed (second contact) ...	...	...	...	...	...	...	...	...	...	38·6
Series II.—										
13-foot single coke-bed (crude sewage) ...	...	53·3	...	47·2	...	...	...	...	...	48·1
13-foot single coke-bed (roughly settled sewage)	...	...	62·9	57·8	52·6	52·2	...	...	57·2	54·6
13-foot single coke-bed (settled sewage) ...	...	...	...	...	...	...	56·6	55·7	56·6	55·7
4-foot single coke-bed (continuous flow of settled sewage)	...	...	...	...	...	...	...	...	40·8	48·9
Settling channels (Dec. 21st 1899 to Jan. 13th 1900)	...	...	...	...	...	...	...	...	16·1	00·4
Small tank coke-bed (settled sewage) ...	...	...	...	...	...	...	...	...	...	52·9
Series III.—										
Settling tank (crude sewage)	...	...	...	...	...	...	...	...	12·0	Nil
3-foot single coke-bed No. 1 (settled sewage)	...	...	...	...	...	...	49·7	49·4	53·5	50·9
3-foot single coke-bed No. 2 (settled sewage)	...	...	...	...	...	...	47·2	46·8	53·0	50·9
Chemical treatment and sedimentation, 1900 ...	...	...	...	...	...	...	...	...	25·9	11·7
Chemical treatment and sedimentation, 1901 ...	...	...	...	...	...	...	...	...	29·6	12·2

Table XIII.—Average percentage purification of the Crude Sewage effected by the Various Methods of Experimental Bacterial Treatment and by the "Chemical Treatment" carried out at the Outfall Works.

The amount of purification effected is calculated from the figures representing the amount of oxygen absorbed from permanganate by the crude sewage and by the final effluent from each treatment.

	One filling of the bed per day or less.		Two fillings of the bed per day.		Three fillings of the bed per day.		Four fillings of the bed per day.		During the whole experiment.	
	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.	By the crude liquid.	By the clear liquid.
Northern Outfall.										
The one-acre coke-bed—										
Bacterial treatment of the "chemical" effluent 1900	...	...	...	...	...	...	...	...	91·3	84·9
Bacterial treatment of the "chemical" effluent 1901	...	...	...	...	...	...	...	...	91·1	84·2
Bacteria beds. Series I.—										
Bacterial treatment of crude sewage in—										
(*a*) Ragstone-beds (two contacts)	...	46·8	...	51·6	...	...	...	...	...	49·1
(*b*) Coke-beds (two contacts)	...	64·9	...	61·5	...	...	...	...	...	63·2
Coke-beds. Series II.—										
Bacterial treatment of crude sewage in—										
(*a*) Coarse coke-beds (two contacts) ...	68·9	62·8	70·1	64·2	...	...	...	...	69·7	63·5
(*b*) Coarse and fine coke-beds (two contacts)	84·2	77·6	81·4	72·2	...	...	...	...	82·1	74·6
Coke-beds. Series III.—										
Bacterial treatment of settled sewage in—										
(*a*) Fine coke-bed	...	...	...	...	...	...	...	...	73·8	60·8
(*b*) Coarse coke-bed	...	...	...	...	...	...	...	...	60·6	51·8
Chemical treatment and sedimentation, 1900 ...	...	...	...	...	...	...	...	...	32·8	Nil
Chemical treatment and sedimentation, 1901 ...	...	...	...	...	...	...	...	...	25·8	Nil
Southern Outfall.										
Coke-beds. Series I.—										
Bacterial treatment of crude sewage in—										
(*a*) A single coke-bed	...	...	...	...	...	...	...	...	...	52·8
(*b*) Double coke-beds (two contacts) ...	...	...	...	...	...	...	...	...	...	69·3
Coke-beds. Series II.—										
Bacterial treatment of crude sewage in a 13-foot coke-bed	...	53·3	...	47·2	...	...	...	...	...	48·1
Bacterial treatment of roughly settled sewage in a 13-foot coke-bed	...	...	62·9	57·8	52·6	52·2	...	...	57·2	54·6
Bacterial treatment of settled sewage in a 13-foot coke-bed	...	...	...	...	...	...	56·6	55·7	56·6	55·7
Bacterial treatment of settled sewage in a 4-foot coke-bed (continuous flow)	...	...	...	...	...	...	...	...	40·8	48·9
Bacterial treatment of settled sewage in a small tank coke-bed	...	...	...	...	...	...	...	...	...	58·7
Coke-beds. Series III.—										
Bacterial treatment of settled sewage in coke-beds (average of 2 single beds)	...	...	...	...	...	...	53·3	54·5	58·7	55·8
Chemical treatment and sedimentation, 1900 ...	...	...	...	...	...	...	...	...	25·9	11·7
Chemical treatment and sedimentation, 1901 ...	...	...	...	...	...	...	...	...	29·6	12·2

V.—TABULATION OF INFORMATION RESPECTING THE BACTERIAL OR NATURAL TREATMENT OF SEWAGE AT VARIOUS CENTRES THROUGHOUT THE COUNTRY.

The information set forth in the following tables has been courteously supplied by the various local authorities throughout the country, who have used bacteria beds in connection with the treatment of sewage or sewage effluent, either in a permanent installation or in an experimental form.

In consequence of the necessarily complicated nature of any attempt to arrange in systematic order the results of such work carried out under very varying conditions, some explanation of the tables and of their arrangement is necessary.

The information has been placed in two main divisions, one dealing with the bacteria beds and the other dealing with the septic tanks; there is also an additional column for remarks.

The division dealing with the bacteria beds is divided into three tables, as follows—

Table 1.—Particulars of the bacteria beds.
Table 2.—Particulars as to the working of the bacteria beds.
Table 3.—Particulars as to the capacity of the bacteria beds, and as to the loss of capacity during working.

The division dealing with the septic tanks is divided into two tables, as follows—

Table 4.—Particulars of the septic tanks (if used).
Table 5.—Particulars as to the working of the septic tanks.

Table 1 is a record of the details of the construction of the various beds used by the different local authorities. In some instances, more especially in centres where reports have been published of the work which has been carried out in the bacterial treatment of sewage, the details of the various beds are very full, and in these cases each bed is dealt with separately. In other instances, principally where the treatment is of a permanent character and the beds are frequently uniform in size and structure, the groups of beds only are described.

In the column "Material and size of the material of which the beds are composed," the size is determined by the mesh of the sieves used in screening the material, unless otherwise stated. Thus, $\frac{1}{2}$ inch to $\frac{1}{16}$ inch means that the material is such as would pass through a screen of $\frac{1}{2}$ inch mesh and would not pass through a screen of $\frac{1}{16}$ inch mesh.

Table 2 is a record of the different experiments which have been carried out at the various centres, but in many instances the records are insufficient to justify the results being set out separately in the table. In such instances only the general details of the manner in which the beds have been worked are recorded. In the case of permanent installations, where the beds have been uniformly dealing with the same class of liquid for some years, only the more recent results are given in the table.

It was found convenient to insert the columns under the heading "Particulars of the settling and of the detritus tanks" in this table, although they do not afford any information as to the working of the bacteria beds.

The figures in the column "Quantity of sewage treated in 24 hours per acre of bed one foot deep" have been calculated from data given, in order that the quantities dealt with by the various beds at a uniform depth, may be seen at a glance.

Table 3.—The importance of information bearing on the capacity of the beds and on the loss of capacity noticed in the working of the beds, rendered it necessary to devote a table to this subject. The records in this table are not intended to correspond with the experiments detailed in the previous table; they are merely such records as have been made of the variations in the capacity of beds. In some instances the records furnished were too extensive to insert in these tables; in such instances extracts have been made from the data supplied.

In the column "Capacity, when empty, of the tank containing the bed" figures are given representing the capacity of the tank before the coke was placed in it. In such cases, where the whole depth of the tank is not occupied by the material of which the bacteria bed is composed, the capacity is given only of that portion of the tank which is occupied by the material.

The original water-capacity of the bed in the tank means the liquid capacity of the bed after the material of which it is formed has been thoroughly soaked. The original water-capacity therefore does not mean the quantity of liquid which could be poured into the bed in its dry condition, but rather the quantity which could be drained from the working bed during the specified time of emptying.

Since the capacity of a bed alters considerably during a lengthened period of rest, the returns have usually included measurements which have been made after such rest periods. Such measurements have not always been made from the first filling after a rest period, and in such instances a draining period is generally recorded as well as the number of fillings since the rest period.

Table 4 furnishes details concerning the septic tanks used at the various centres.

Table 5 is a record of the working of the septic tanks.

The information in these tables has been brought up to 30th April, 1902.

Table 1. PARTICULARS OF THE

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
1	Accrington	P.	10	...	3,019	62 feet in diameter each		8·5 and 9	Coke, 2 inch to 3 inch mesh
			4	...	1,944	49 feet 9 inches in diameter each		8 and 9	" " "
2	Aldershot	P.	...	Top or primary	2,146	58×37	...	4	Clinkers, $\frac{3}{8}$ inch ...
									" varying size...
				Bottom or secondary	5,800	58×100	...	1·5	" generally fine
3	Acton	T.	...	...	...	...	...	6·5	
4	Aylesbury	T.	4	...	31,740 total area	Varies from 50×30 to	116×30	5·0	Coarse burnt ballast ...
			6					3·25	Coke breeze ... ...
5	Barnsley	T.	3	...	32,400	120 × 90	...	3	Broken clinker and ashes $\frac{1}{4}$ inch mesh...
									$\frac{1}{2}$ " ...
									1 " ...
									$1\frac{1}{2}$ " ...
6	Birmingham	T.	8	1 to 8	133,656	150×150	$148\frac{1}{2}$×$148\frac{1}{2}$	3	Coke, 1 inch to $1\frac{1}{4}$ inch
					44,552	150×150	$148\frac{1}{2}$×$148\frac{1}{2}$	3	Destructor clinker, 1 inch to $1\frac{1}{4}$ inch
7	Blackburn	T.	1	...	4,770	...	...	5·5	Coke ... ...
			1	...	4,770	...	...	5·5	Coke breeze ... ...
8	Bloxwich district of Walsall	T.	8	Primary ...	...	...	...	2·5	$\frac{1}{2}$ inch to $\frac{1}{16}$ inch ...
			8	Secondary ...	...	...	...	2·5	$\frac{1}{2}$ inch to dust ... ...
9	Bristol—								
	At Knowle	T.	2	Knowle ...	132 each	22×6	22×6	6	Washed clinker from destructor which passed through a 2 inch ring
	At St. John's-lane...	T.	1	St. John's ...	396	$22\frac{1}{2}$ diameter	30 diameter	3	

Bacteria Beds.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
...	Half 18 inch perforated earthenware pipes laid on concrete bottom	2 5 – per sq. yard. Including excavation, concreting bottom, underdraining, brickwork in cement and coke.	10,890 – –	4 6 – (about)
15 inches ... 33 „	Only by the packing of large material. No pipes are used	250 – – 220 – –	5,000 – – (about) 1,700 – – (about)	
...	9 inch main drains (two mains to each large bed), with double junctions 2 feet apart and 3 inch agricultural pipes arranged in herring-bone fashion	3,200 – – (by contract) for coke breeze beds.	6,400 – –	15 – –
9 inches ... 9 „ ... 9 „ ... 9 „ ...	By land tiles and square longitudinal drains 18 inches by 12 inches	1,343 10 9	1,400 – – (about) including the open septic tank	
Similar throughout	The whole bed is laid on a false bottom, in which there are channels 6 inches by 6 inches and 148 feet long	48,000 – – (about)	12,000 – – (about)	
Similar throughout	3 inch agricultural drain tiles laid herring-bone fashion in channels covered with 2 inch stone covers. There is a fall of 18 inches in each bed			
...	Land tiles	1,000 – –	5,000 – –	
...	No pipes, floor inclined from centre to border			

Table 2.

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks.		
					Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
1	Accrington	Aug., 1899 to date	...	Sewage which has passed through a detritus chamber provided with a fixed screen, and which has afterwards passed through two sets of septic tanks, each set consisting of three tanks. The sewage is distributed on the beds by means of sprinklers	All the detritus and sand is left either in the detritus chamber or two first septic tanks. Storm water is separate		
2	Aldershot	...	...	Crude sewage after having passed through a small detritus chamber. No screening. Storm water is separate from sewage	...	...	...
3	Acton	...	...	... ...	...	...	...
4	Aylesbury	...	...	Sewage which has previously passed through a settling tank	40,000	50 × 30	250,000
5	Barnsley	During the last 12 months	1, 2 and 3	Only night water which has previously passed through a septic tank is treated, not sewage. Road detritus and sand are separated from the liquid	200,000	90 × 120	200,000 (about)
6	Birmingham	Less than six months	...	Storm water and excess sewage from Rea main sewer	5,441,875	315 (average)	22,000,000
7	Blackburn	2 years ...	...	Screened sewage which has been from 12 to 16 hours in the septic tank			
8	Bloxwich district of Walsall	...	...	Sewage which has passed through a septic tank	...	...	...
9	Bristol— At Knowle	Two years	...	Sewage which has passed through a septic tank	...	...	...
	At St. John's-lane...	Two years	...	Do. do.			

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aeration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
...	...	Continuously worked				...	1	215,111	90·0	4	70	91·3
Nil	...	...	...	...	...	2½	2	Primary beds deal with about 500,000 gallons per day	91·0	4	80	90·6
		Secondary beds worked on continuous flow principle				...	...	Secondary beds deal with about 130,000 gallons per day				
...	...	Continuous method (Whittaker and Bryant sprinklers are used)			...	...	...	About 372,300				
...	...	Varies according to flow from the town	2	½ and 1	2	...	...	A minimum quantity of 250,000 gallons to the six coke breeze beds (about ½ acre) per day	(60 to 80 per cent. purification is effected.)			
Lime Alumino ferric		Depends upon the night flow and weather	...	...	...	1	1					
None	...	2	7	3	12	1	1	Varies	53·5	4	80	
None		Varied during the experiments			...	2 and 3	2	...	75 to 80	4	80	97·1
...	...	1	2	1	3	2½	2	...	96·3	4	...	97·7
...	...	Continuous process			...	...	1	1,048,666 Stoddart distributor used	92	4	80	94
		"		"		...	1	204,893 Candy-Caink distributor used	71	4	80	93

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank.		
				Date.	Gallons.	Percentage of the empty tank.
1	Accrington	The beds are The same amo	not ordinary co unt of sewage is	ntact beds, th being passed	e sewage per through the	colates through beds as when
2	Aldershot	No account is	taken of the nu	mber of fillin	gs. The syst	em having gone
3	Acton					
4	Aylesbury					
5	Barnsley	It is expected	that a reductio	n in capacity	will occur.	
6	Birmingham					
7	Blackburn					
8	Bloxwich district of Walsall				5,000	
9	Bristol— At Knowle ... ... At St. John's-lane...	Continuous pr	ocess.			

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		

them.
they were first constructed.

beyond the experimental stage, the beds are brought into use as required.

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks.		Capacity of the tanks.
					Area.	Depth.	
					Feet.	Feet.	Gallons.
1	Accrington	The whole of the tank capacity is a little over $1\frac{1}{2}$ days' flow.					
2	Aldershot	No septic tanks used.					
3	Acton	...	...	Open			
4	Aylesbury						
5	Barnsley	1	...	Open	10,800	3	202,500
6	Birmingham	20	1 to 20	Open	189,000 (square feet)	6·05	7,143,500
7	Blackburn	2 in succession.		Open			750,000
8	Bloxwich district of Walsall	...	...	Open	Tank holds about 6 hours flow of sewage.		
9	Bristol—						
	At Knowle	2	Knowle	Closed	275 and 360	6	26,000 (total)
	At St. John's-lane...	1	St. John's	Closed	200	6	8,125

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
1	Accrington	6 Open	15 months' continuous use	...	1,250,000 (dry weather flow)	...	...	76·7	
2	Aldershot								
3	Acton								
4	Aylesbury								
5	Barnsley								
6	Birmingham	1 to 20	In use constantly	104	22,000,000	...	None	...	*
7	Blackburn	1 2	...	104	240,000	...	...	90·	72· of the suspended solid matter.
8	Bloxwich district of Walsall								
9	Bristol— At Knowle ... ... At St. John's-lane...		January, 1900 to March, 1902		 39,000 1,600				

* The sludge which had to be disposed of before septic tanks were used amounted to double that which is now to be removed from the sedimentation tanks.

No.	Name of town or district.	Remarks.
1	Accerington	The whole of the sewage is treated in a permanent manner, and the results are satisfactory to the Rivers Board. An attempt is being made to reduce the cost of treatment by dispensing with pumping; the coal bill is a very heavy item.
2	Aldershot	
3	Acton	The experiment was successful, and the effluent which was delivered into the tideway of the river at Chiswick Ait, was approved of by the Thames Conservancy. Arrangements are being made for open septic tanks and continuous filters for dealing with the whole of the sewage.
4	Aylesbury	The resnlt is considered satisfactory, and the installation is now permanent.
5	Barnsley	This is a temporary experiment, and the result is considered satisfactory. The tanks and coke-beds have not been sufficiently long in use to afford opportunity for judging proper results.
6	Birmingham	Sewage is applied to 1,828 acres of farm land. Within the last two years precipitation tanks have been converted into septic tanks, and the septicised sewage has been applied to the land. The results obtained from the experimental bacteria-beds, other than the large beds above referred to, were perfectly sufficient to show that the sewage could be efficiently treated in bacteria-beds.
7	Blackburn	The temporary beds have been thrown out of use, and 24 beds 120 feet long by 60 feet wide and $3\frac{1}{2}$ feet deep are now in course of construction.
8	Bloxwich district of Walsall	The population of the area drained is 2,200. A large sceptic tank is in course of construction. First-class results have been obtained up to the present.
9	Bristol—	
	At Knowle	The effluent discharges into a brook which passes through a village; an application for an injunction to stop the works was dismissed, as the judge was satisfied as to the purity of the effluent.
	At St. John's-lane...	The works are surrounded by dwelling-houses, one being less than 50 feet distant.

PARTICULARS OF THE BACTERIA BEDS, ETC., AT VARIOUS CENTRES.

Table 1. PARTICULARS OF THE

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
10	Burnley—			*					
	Duck pits (septic tanks) and Woodend works (beds)	P.		1 P	30,927				Furnace clinker above ½ inch mesh
				2 P	31,363				Coarse clinker
				3 P	27,878				
				4 P	28,134				
				5 P	28,314				
				6 P	54,540				
				11 P					
				14 S	26,136				Furnace clinker ¼ inch to ½ inch mesh
				16 S	27,442				Coarse clinker
				17 S	27,178				
				18 P	21,780			3	Engine ashes ... ...
				19 S	21,780			3	Coke screened to 1½ inch mesh
				22 S	20,909				Engine ashes ⅛ inch to ¼ inch mesh
				23 S	20,909				Engine ashes ⅛ inch to ½ inch mesh
	Altham works (septic tanks and beds)			1 P	5,227				
				2 P	13,068				
				3 P	12,632				
				4 P	12,632				
				5 S	4,792				
				6 S	13,504				
				7 S	12,632				
				8 S	12,632				

*In this column, P indicates a Primary bed, S indicates a Secondary bed.

Bacteria Beds.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	
			1,200 – –	
9 inches at bottom				
9 inches at bottom	Socketed 12 inch earthenware pipes and 4 inch field tiles			

Table 2.

PARTICULARS AS TO THE WORKING

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks. Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
10	Burnley— Duckpits (septic tanks) and Woodend works (beds)	1898-1901 Feb. to Mar.	18	Septic tank effluent	...	...	...
		1898 Apl. to Sep.	19	Septic tank effluent	...	...	...
		1898-1901 July to Mar.	22	Coke-bed effluent from No. 18 bed	...	...	...
		1899-1901 Oct. to Mar.	2	Septic tank effluent	...	...	...
		Oct. to Mar.	23	Coke-bed effluent from No. 2 bed	...	...	...
		1899-1901 Dec. to Mar.	1	Septic tank effluent	...	...	...
		1900-1901 Jan. to Mar.	19	Coke-bed effluent from No. 1 bed	...	...	...
		1900-1901 June to Mar.	5	Septic tank effluent	...	...	...
		1900-1901 July to Mar.	14	Coke-bed effluent from No. 5 bed	...	...	...
		1901-1902 3 June to 31 March	...	Septic tank effluent	...	...	...
		1901-1902 14 Aug. to 31 March	...	Coke-bed effluent	...	...	...
		1902 10 Feb. to 31 March	6	Septic tank effluent	...	...	...
		1902 17 to 31 March	15	Coke-bed effluent	...	...	...
	Altham works (septic tanks and beds)	1900-1901 Feb. to Mar.	1	Septic tank effluent	...	...	...
		Feb. to Mar.	5	Coke-bed effluent from No. 1 bed	...	...	...
		1900-1901 Oct. to Mar.	2	Septic tank effluent	...	...	...
		Oct. to Mar.	6	Coke-bed effluent from No. 2 bed	...	...	...
		1901-1902 25 April to 31 March	3	Septic tank effluent	...	...	...
		1901-1902 10 Feb. to 31 March	7	Coke-bed effluent from No. 3 bed	...	...	...

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aeration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
Lime ...	0·42	...	2	...	...	...	1		56·8	4	80	52·5
...	...	...	2	...	...	...	1		43·1	4	80	43·9
...	...	...	...	...	...	...	2		88·5	4	80	87·2
...	...	1½	2	...	...	...	1		60·2	4	80	54·4
...	...	...	...	...	...	...	2		86·3	4	80	84·7
...	...	...	...	...	...	...	1		56·3	4	80	53·5
...	...	...	...	...	...	...	2		85·6	4	80	85·1
...	...	...	...	...	...	...	1		57·9	4	80	54·8
...	...	...	...	...	...	...	2		87·0	4	80	84·2
...	...	...	...	...	...	...	1		58·6	4	80	50·1
...	...	...	...	...	...	...	2		78·0	4	80	79·9
...	...	...	...	...	...	...	1		51·1	4	80	52·3
...	...	...	...	...	...	...	2		73·8	4	80	83·8
...	...	...	...	...	...	...	1		68·0	4	80	59·6
...	...	...	...	...	...	...	2		87·7	4	80	87·5
...	...	...	...	...	...	...	1		76·0	4	80	64·6
...	...	...	...	...	...	...	2		83·4	4	80	85·9
...	...	...	...	...	...	...	1		60·4	4	80	57·1
...	...	...	...	...	...	...	2		85·4	4	80	80·2

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed.	Original water capacity of the bed in the tank.		
			Gallons.	Date.	Gallons.	Percentage of the empty tank.
10	Burnley— Duck pits (septic tanks) and Woodend works (beds)					
	Altham works (septic tanks and beds)					

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks. Area. Feet.	Dimensions of the tanks. Depth. Feet.	Capacity of the tanks. Gallons.
10	Burnley—						
	Duck pits (septic tanks) and Wood-end works (beds)	12	1	Open	50 by 40	7·75	99,000
			2	"	"	"	"
			3	"	"	"	"
			4	"	"	"	"
			9	"	"	"	"
			10	"	"	"	"
			11	"	"	"	"
			12	"	"	"	"
			5	"	75 by 40	6·75	120,250
			6	"	"	"	"
			7	"	"	"	"
			8	"	"	"	"
	Altham works (septic tanks and beds)	4	1	Open	39 by 12	5·75	16,700
			2	"	23 in diameter	14·33	37,200
			3	"	"	"	"
			4	"	"	"	"

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
10	Burnley—								
	Duck pits (septic tanks) and Wood-end works (beds)	...	...	17 weeks					
	Altham works (septic tanks and beds)								

Table 1.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
11	Burslem...	T. P.	9	Primary ...	144,000 (total)	...	...	3	Pottery refuse, $\frac{1}{2}$ inch to $1\frac{1}{2}$ inch mesh
				Secondary ...	...	...	...	3	
				Tertiary ...	...	...	...	3	Pottery refuse, $\frac{1}{2}$ inch to 1 inch mesh
12	Bury	P.	6	...	8,100	45 × 30	45 × 30	3	Coke } $\frac{5}{8}$ inch to $1\frac{1}{2}$
			6	...	8,100 (totals)	45 × 30	45 × 30	3	Cinders } inch mesh
13	Cambridge	...	2	...	9,800 (total)	...	(8,700 superficial feet)	10	Clinkers, 2 inch to $\frac{3}{4}$ inch ,, $\frac{5}{8}$ inch to $\frac{1}{3}$ inch ,, above 2 inches
14	Carlisle	P.	4	1, 2, 3, 4 ...	5,400 (each)	120 × 45	120 × 45	4	Sandstone, 5 inch to 1 inch mesh
15	Croydon...	P.	6	...	5,140	Irregu	lar	3·75	Coarse burnt clay ballast 1 inch to 3 inch mesh
16	Darwen	P.	5	...	...	49 × 24	...	3·5	Sand, $\frac{1}{26}$ inch to $\frac{1}{16}$ inch mesh Hard vitrified clinker ...
17	Epsom	...	6	Primary ...	...	...	...	3	$1\frac{1}{2}$ inch mesh
				Secondary ...	...	...	...	...	$\frac{1}{2}$ inch mesh

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
6 feet 2 feet 2 feet	Covered channels in the concrete bottoms of the tanks packed around with coarser material		2,740 – – (Estimated cost of extensions now being made, exclusive of filling.)	
Not in layers	Not underdrained	2,550 – –	5,100 – –	
All the same size	3 inch agricultural drain pipes, 5 feet apart, leading to central drain	2,600 – – (about)	3,660 – –	
6 inch 3 feet	Channels in the concrete floors of the beds, covered with stone flags			

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks.		
					Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
11	Burslem...	...	...	Sewage which has been screened and passed through a septic tank	...	...	...
12	Bury	Since Mar., 1900	...	Sewage which has passed through a screening tank and been chemically treated and sedimented	50,000 6 circula tation	(each) r precipi- tanks	2,000,000
13	Cambridge	...	...	Storm flow more especially	...	...	...
14	Carlisle	2 years	...	Sewage which has been screened	...	...	...
15	Croydon	2 years	...	Sewage which has been screened	41,000	1,500	450,000
16	Darwen	About 3 years	1 to 5	Sewage which has passed through a precipitation tank to remove as much solid matter as possible	Capacit dry	y about o weather	ne day's flow.
17	Epsom	...	...	In one case sewage from a septic tank, and in the other case sewage from land	...	...	...

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place °F.	
...	...	1	2	1	4	3	3	242,000				
Ferro-zone or alumino-ferric	6 to 7	1½	1½	1½	1½	4	...	333,333				
...	...		Streaming method of supply to beds									
...	...	1½	2	1½	2	3	2	223,926	38	4	80	40
			Night sewage is treated continuously in these beds						(by coarse bed)			
									47	4	80	49
									(by coarse bed and sand)			
									58	4	80	52
									(by experimental bed, $\frac{1}{8}$ in. mesh)			
									79	4	80	75
									(by experimental bed, $\frac{1}{32}$ in. mesh)			
...	...	1⅓	2	1⅓	2½	2	1	169,500	63·8	4	...	60·7
Alumino-ferric	7	8	hours		4	2	1	333,333				
...	...	...	2	...	...	3						

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank.		
				Date.	Gallons.	Percentage of the empty tank.
11	Burslem...					
12	Bury		A slight decrease in capacity has been noticed; probably due to overwork.			
13	Cambridge					
14	Carlisle	4	135,000	Sept., 1900	54,319	40
15	Croydon...					
16	Darwen		The capacity of our bacteria beds was reduced by $\frac{1}{3}$rd.			
17	Epsom					

BEDS AND AS TO THE LOSS OF CAPACITY DURING WORKING.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
Sept, 1901	44,642	33	...	7	9,677	17		

Throughout the year the beds are in use for three weeks continuously, and then rest for one week.

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks.		Capacity of the tanks.
					Area.	Depth.	
					Feet.	Feet.	Gallons.
11	Burslem...	...	...	Open			
12	Bury	None used.					
13	Cambridge						
14	Carlisle	No septic tank					
15	Croydon...	No septic tank					
16	Darwen	The septic experiments were not very successful.					
17	Epsom	...	...	...	...	...	11,000

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
11	Burslem...								
12	Bury								
13	Cambridge								
14	Carlisle								
15	Croydon...								
16	Darwen								
17	Epsom								

No.	Name of town or district.	Remarks.
11	Burslem...	The information respecting this centre has been obtained from particulars referring to a scheme in preparation, published by the Borough of Walsall.
12	Bury	From the results obtained, the Corporation have decided to extend the works on similar lines.
13	Cambridge	
14	Carlisle	
15	Croydon...	About 450,000 gallons are dealt with daily. The effluent is passed over land once or twice by surface irrigation.
16	Darwen	The sludge from the precipitation tanks is allowed to flow into a large lagoon formed in the deep bed of coarse gravel on which the sewage works are situated. A great deal of liquefaction takes place in this bed, thus causing the disappearance of the greater part of the sludge. The beds were originally of coke, but owing to the diminution caused by the breaking down of the coke, hard vitrified clinker has been substituted.
17	Epsom	The information respecting this centre has been obtained from particulars published by the Borough of Walsall.

PARTICULARS OF THE BACTERIA BEDS, ETC., AT VARIOUS CENTRES.

Table 1.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
18	Evesham	P.	4	1 to 4	20,000	...	...	3·5	Slag $\frac{1}{4}$ inch to $1\frac{1}{4}$ inch.
19	Glasgow	...	4	First contact beds	3,594 (total)	...	...	3·25	Engine ashes, $\frac{1}{4}$ inch mesh " $\frac{1}{2}$ " " $\frac{3}{4}$ " " $\frac{1}{8}$ " " $\frac{1}{4}$ " " $\frac{1}{2}$ "
			4	Second contact beds	3,582 (total)	...	...	3·25	
20	Haslingden, Rawtenstall and Bacup	P. T.	16	...	...	45 × 30	...	3.	Fine clinker ... ... Coarse and fine coke ... Burnt ballast and aërating pipes Coarse coke ... ... Burnt ballast and 4 inch drain pipes. Afterwards the 6 inches of fine clinker were replaced by 1 foot of coarse clinker
21	Heywood	T.							

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
Mixed	Perforated pipes	1,000 – – (filling only)	4,600 – –	
9 in. 1 ft. 9 in. 9 in. 2 ft. 7 in. 8 in.	Dry built brick drains, 9 inches by 9 inches in the centre of the bed and 4 inch field drain pipes laid diagonally from the centre to the sides	The installation, which is merely experimental and on a very small scale cost £980. The original cost of the precipitation tanks which contain the beds is not taken into account.		
6 in. 14 in. 4 in. 8 in. 4 in.	4 in. drain tiles surrounded with burnt ballast	5,800 – –		

Table 2. PARTICULARS AS TO THE WORKING

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks.		
					Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
18	Evesham	Beds not yet completed					$\frac{1}{6}$ of daily flow
19	Glasgow	...	...	Open septic tank effluent derived from crude sewage which contains a large quantity of trades' effluent of a variable nature	...	...	...
20	Haslingden, Rawtenstall and Bacup	...	...	Sewage which had been screened and which had passed through a septic tank	1,825,000 (4 tanks each 60 feet wide)	180	.1,825,000
21	Heywood	...	...	Sewage from septic tank ... ... Sewage which had been chemically precipitated	... ...	... ...	... ...

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
None	used											
None ...	...	½	2	1	2 to 3	1 to 3	2	36,814 One filling daily	95	4	80	90·6
...	...	3	1	1	14	2	...	...	86	4	80	90
		Partly meth	on the od	contin	uous	...	...	...	79·6 (Both are cal on the tank e	4 figures culated septic ffluent)	80	87·1
...	...	...	...	...	...	...	1					
...	...	...	...	...	...	...	...	...	60			

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank. Date.	Gallons.	Percentage of the empty tank.
18	Evesham					
19	Glasgow	4 1st contact beds	72,996	17 Sept., '00	36,498 32,617	50 (estimated) 44·6 (actual)
20	Haslingden, Rawtenstall and Bacup ...					
21	Heywood					

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
Dec., '00	19,700	26·9	...	...	12,917	39·6	101 days	167
Mar., '01	17,492	23·9	...	...	2,208	6·8	83 ,,	213
May, '01	21,412	29·3	...	19	3,920 gain	12·0	44 ,,	88
Aug., '01	20,321	27·8	...	...	1,091	3·3	87 ,,	174
Nov., '01	21,839	29·9	...	25	1,518 gain	4·7	76 ,,	152
Dec., '01	18,981	26·0	...	...	2,858	8·8	22 ,,	22
Jan., '02	19,046	26·0	...	...	65 gain	0·2	42 ,,	42
Mar., '02	17,997	24·6	...	...	1,049	3·2	58 ,,	88

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks. Area. Feet.	Dimensions of the tanks. Depth. Feet.	Capacity of the tanks. Gallons.
18	Evesham	3	1 to 3	Open	1,780	4·5	150,000
19	Glasgow	1	...	Open	3,881	8·25	200,000
20	Haslingden, Rawtenstall and Bacup	4	...	Open	10,800 (each)	7·5 (average)	456,250 (each)
21	Heywood						

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
18	Evesham	...	...	25	150,000				
19	Glasgow...	1	15 Sept., 1900, and 2 May, 1901	33	...	14,525,128	818·5	92	54·25
20	Haslingden, Rawtenstall and Bacup	...	Dec., 1899 to Dec., 1901.	104	456,250	47,000,000	Average depth of 3 feet in tank)	90	
21	Heywood								

No.	Name of town or district.	Remarks.
18	Evesham	
19	Glasgow...	
20	Haslingden, Rawtenstall and Bacup	After two years' working it was found necessary to clean out the tanks on account of large upheavals of black sediment. The black sediment had a strong odour of sulphuretted hydrogen. It had a tendency to choke both the artificial and land filters. Periodical cleaning out has since been adopted.
21	Heywood	The information respecting this centre has been obtained from particulars published by the Corporation of Manchester.

PARTICULARS OF THE BACTERIA BEDS, ETC., AT VARIOUS CENTRES.

Table 1.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds.	Measurement of the beds. At top.	Measurement of the beds. At bottom.	Depth of the beds.	Material and size of the material of which the beds are composed.
					Square feet.	Feet.	Feet.	Feet.	
22	Huddersfield	T.	2	Coarse	1,600	40 × 40	40 × 40	3·5	Clinker, $\frac{5}{8}$ inch to 5 inch mesh
				Fine	1,800	...	...	3·25	Clinker, $\frac{1}{4}$ inch to $\frac{5}{8}$ inch mesh
									Clinker, $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch mesh
									Clinker, rough ... ...
			24	No. 10 ... ... (One bed given as a type)	1,800	48 × 38	48 × 38	3·25	Furnace clinker, $\frac{1}{4}$ inch to $\frac{5}{8}$ inch mesh
									Furnace clinker, $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch mesh
									Rough clinker ... ...
			2	Coarse bed ...	288	16·5 × 18·5	15·5 × 17·5	3·75	Destructor clinker, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch mesh
									Destructor clinker, 1 inch to 3 inch mesh
				Fine bed ...	288	16·5 × 18·5	15·5 × 17·5	3·75	Destructor clinker, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch mesh
									Destructor clinker, $\frac{3}{16}$ inch to 1 inch
23	Hyde	...	1	...	45 (diameter)	...	...	9	Coke rejected by 3 inch mesh
24	Keighley	T.	2	Rough bed ...	100	10 × 10	10 × 10	3·25	Coke, 1 inch to 3 inch mesh
				Fine bed ...	...	...	...	...	$\frac{1}{4}$ inch to 1 inch mesh
25	Kettering	T.	1	...	210	21 × 10	21 × 10	3	Gravel pebbles
									Coke $\frac{1}{4}$ inch to 1 inch mesh
		P.	2	...	16,268	170 × 102	162 × 94	4	Coke breeze, $\frac{3}{16}$ inch to $1\frac{1}{2}$ inch mesh
			1	...	16,268	170 × 102	162 × 94	4	Coke breeze, $\frac{3}{16}$ inch to $1\frac{1}{2}$ inch mesh
			1	...	12,782	170 × 81	162 × 73	4	Burnt ballast, $\frac{1}{2}$ inch to 2 inch mesh
	A layer of iron furnace slag, 2 inches in thickness, was placed on the top of each bed.								

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
3 feet 6 inches	Land tiles	£ s. d.	£ s. d.	£ s. d.
9 inches	" "			
1 foot 11 inches				
7 inches 10 inches	" "			
2 feet				
5 inches 3 inches (over part only)	" "			
6 inches	" "			
3 feet 3 inches				
9 feet	Half tiles on bricks, concrete floors	150 – –	180 – –	
...	Land tiles	...	4,500 – –	
3 inches 2 feet 9 inches	Land drain tiles, 2 inches in diameter laid herring-bone fashion to 3 inch central drain			
4 feet ... 2 feet ... 2 feet ...	Main drain with cemented joints up centre of each bed, 12 inches in diameter for one-half the length, 9 inches for the other. Side drains, land tiles 2 inches in diameter, butt jointed, 5 feet apart, laid herring-bone fashion.	5,000 – – (about)	3,540 – –	

Table 2.

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks. Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
22	Huddersfield	10 Aug., '98 to 23 Jan., '00	...	Sewage which had passed through a fine plate with $\frac{1}{16}$ inch perforations Effluent from coarse bed	Detritus was settled in a trough and removed from time to time		
		July, '98 to present time		Sewage which had been chemically treated and sedimented	1,250,000 (Total of 24 tanks)	...	6,000,000
		Aug., '00 to present time		Sewage which had passed successively through a screen of 1 inch mesh, a small detritus tank and a septic tank Effluent from coarse bed	Small detritus tank used		
23	Hyde	3 years ...	...	Crude sewage which had passed through the septic tank	75,000	90	75,000
24	Keighley	18 months	...	Sewage which had passed through detritus and sedimentation tanks	687	10	3,840
25	Kettering	About 4 years	...	Sewage which has passed through precipitation tanks	Precipitation tanks are used, two of which are Dortmund tanks, each 25 feet in diameter and 40 feet deep to bottom of cone. Capacity of each 80,000		
					35,970	60	
					35,700	60	
					35,700	60	
					34,860	60	
					34,270	60	
					49,590	84	
					49,590	84	
					49,120	84	

of the Bacteria Beds.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
...	...	1	2	1	...	2	...	83,733	66	4 (1st contact)	80	66
						2	2	...	79	4 (2nd contact)	80	80
Lime ...	3·5	1	2	1	...	3	...	240,000	78	4 (1st contact)	80	79
Sulphate of iron	2·9					3	2	...	88	4 (2nd contact)	80	87
...	...	1	2½	1	...	2 and 3	...	170,000	71	4 (1st contact)	80	71
	...	...	...	...	...	2 and 3	2	...	82	4 (2nd contact)	80	81
None ...	...	Continuous		...	...	...	...	2,178,000	85·7	4	...	90
None ...	...	Varied		...	...	...	2	126,000	...			
None ...	...	3 (varies)	1	2 to 3	1 (varies)	2 or 3	1	31,250	50 (Purification of tank effluent)	4	80	35

Table 3.

PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed.	Original water capacity of the bed in the tank.		
			Gallons.	Date.	Gallons.	Percentage of the empty tank.
22	Huddersfield	Coarse bed	34,931	9 Aug., 1898	19,000	54·4
		No. 10	36,392	25 July, 1898	19,940	54·8
		Coarse bed (septic series)	6,738	22 Aug., 1900	3,990	59·2
		Fine bed (septic series)	6,738	22 Aug., 1900	3,900	57·9
23	Hyde	No loss of capacity so far as determined. Now working at higher speed				
24	Keighley	...	1,980	...	...	...
25	Kettering	Fine sludge from the precipitation tanks clogs the surface of the beds, but in favourable weather the surface of the beds is loosened with a fork. This greatly improves the working of the beds. Road detritus appears to be retained in the Dortmund tanks, through which the sewage first flows.				
		3 beds	406,000 each	June to Aug., 1898	170,000	41·8
		1 ,,	320,000	Not measured		

BEDS AND AS TO THE LOSS OF CAPACITY DURING WORKING.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
3 Mar., '99	9,000	25·8	...	0	10,000	52·6	29 weeks	317
31 May, '99	7,300	20·9	...	0	1,700	8·9	13 ,,	148
11 July, '99	6,100	17·5	...	0	1,200	6·3	6 ,,	70
17 Oct., '99	5,600	16·0	...	0	500	2·6	14 ,,	156
24 Jan., '00	4,800	13·7	...	0	800	4·2	14 ,,	164
10 Feb., '02	7,900	21·7	3	0	12,040	60·4	185 ,,	2,881
13 Jan., '02	1,770	26·3	3	0	2,220	55·6	73 ,,	
13 Jan., '02	2,280	33·8	3	0	1,620	41·5	73 ,,	
than before.								
8 Mar., '02	660	33	...	None.				
...	130,000 (average)	32·0	2 to 3	...	40,000	23·4	Since 1898	

Each bed rests 1 week and works three weeks when practicable.
Figures relating to capacity are working averages.

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks.		Capacity of the tanks.
					Area.	Depth.	
					Feet.	Feet.	Gallons.
22	Huddersfield	1	...	Open	1,590	5·5	50,000
23	Hyde	1	...	Open	...	...	75,000
24	Keighley	...	...	Open	540	3·7	8,750
25	Kettering	Septic action apparently occurs in the precipitation tanks.					

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
22	Huddersfield	...	22 July, 1900, to 29 May, 1901	44	50,000 (about)	15,232,000	107·88	91·3	88
23	Hyde	1	June, 1899 to 1902	3 years	75,000	...	11 tons in 14 months		
24	Keighley	...	July, 1900 to April, 1902	91	Varies				
25	Kettering								

No.	Name of town or district.	Remarks.
22	Huddersfield	That by no process can the formation of sludge be obviated. When the crude sewage is treated in contact beds, the rapid accumulation of matter in the beds renders the process impracticable. That by the use of a small quantity of lime and copperas (sulphate of iron), followed by contact bed treatment, a satisfactory effluent can be produced. That the contact beds used for the purification of the effluent after chemical precipitation will not retain their capacity indefinitely, and that in the course of a number of years it will be reduced to such an extent as to render necessary the washing or riddling of the material. That by the open septic process 38 per cent. of the sludge is destroyed. The septic effluent is not as amenable to subsequent contact bed treatment as the effluent from chemical precipitation. The capacity of the beds treating the septic effluent decreases more rapidly than that of the beds treating the effluent after chemical precipitation, owing to the excessive amount of suspended matter in the septic effluent. The septic effluent after double contact is frequently unsatisfactory.
23	Hyde	A complete scheme of sewage treatment based upon these results has been submitted to the Local Government Board for approval.
24	Keighley	The council does not intend installing bacteria beds so long as intermittent land filtration is satisfactory.
25	Kettering	The bacteria beds have recently been examined and found to be quite clean inside and without any accumulation of sludge beyond some fine deposit on the surface.

PARTICULARS OF THE BACTERIA BEDS, &c., AT VARIOUS CENTRES.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
26	Leeds	...	...	No. 1 coarse bed	5,580	90 × 65	88 × 63	5	Coke, 3 inch and larger mesh
				2 fine bed...	5,580	100 × 61	99 × 51	6	Coke, $\frac{3}{16}$ inch to $1\frac{1}{2}$ inch mesh
				3 coarse bed	5,445	...	...	3	Clinker, $\frac{1}{2}$ inch to 1 inch mesh
				4 fine bed...	5,445	...	...	3	Clinker, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch mesh
				5 coarse bed	5,445	...	...	3	Clinker, 1 inch to 2 inch mesh
				6 fine bed...	5,445	...	...	3	Clinker, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch mesh
				7 fine bed...	8,100	...	...	3·5	Clinker, $\frac{5}{8}$ inch to 1 inch mesh
				8 fine bed...	4,320	...	...	3·5	Clinker, $\frac{5}{8}$ inch to 1 inch mesh
				Whittaker No. 1	...	...	...	10	Clinker, 1 inch to 3 inch mesh
				,, 2	...	...	...	9·5	Coke above $1\frac{1}{2}$ inch mesh ,, 2 ,, ,,
				1 continuous ...	153	12 × 12 (about)	...	3·6	Coke, coarsest available
				2 ,, ...	,,	,,	...	2·6	Coke, 1 inch to $1\frac{1}{2}$ inch mesh
				3 ,, ...	,,	,,	...	2·6	Coke, about $\frac{5}{8}$ inch mesh
				Ducat	435·6	...	...	10	Clinker, $\frac{3}{8}$ inch to $\frac{5}{8}$ inch mesh

Bacteria Beds.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
...	3 inch agricultural drain pipes, surrounded by large coke			
...	" "			
...	Partly drained by 3 inch pipes and coarse clinker			
...	" "			
...	" "			
...	" "			
...	Not drained			
...	3 inch agricultural drain pipes			
...	9 inch drain pipe in concrete			
... 1 foot	18 inch half-round drain pipes on concrete			
Afterwards 1½ inch & upwards	9 inch drain pipes			

Table 2.

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks. Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
26	Leeds	2 Oct., '97 to 2 Feb., '98	No. 1 coarse bed	Sewage screened by vertical bars one inch apart	Not settled	...	...
			No. 2 fine bed	...	...	...	...
		18 Feb., '98 to 3 Mar., '98	No. 1 coarse bed No. 2 fine bed	Sewage which had been chemically treated and sedimented	...	...	...
		4 Mar., '98 to 8 Sept., '98	No. 1 coarse bed	Sewage which had passed through a fine screen with holes $\frac{1}{8}$ inch diameter	...	...	...
			No. 2 fine bed	...	...	...	...
		9 Sept., '98 to 18 Nov. '98	No. 1 coarse bed No. 2 fine bed	Sewage which had been settled	...	No. 1 settling tank	...
		2 Dec., '98 to 6 Jan., '99	1, 2, 3, 4	Sewage which had been settled	...	...	...
		7 Jan., '99 to 1 June,' 00	1, 2, 3, 4, 5, 6	Sewage from which the grit had been settled	...	...	...
		8 Mar., '99	7	Sewage which had been chemically treated and sedimented	...	...	...
		20 Mar., '99	8	Sewage which had passed through a septic tank	...	...	...
		22 Sept., '99 to 16 June, '00	1, 2, 3, 4, 5, 6	Sewage which had passed through the closed septic tanks	...	...	...
		9 Mar., '99 to 12 May, '00	Whittaker No. 1	Sewage which had passed through No. 1 open septic tank	...	...	...
		2 Sept., '99 to 30 June, '00	Whittaker No. 2	Sewage which had passed through No. 1 open septic tank	...	...	...
			1, 2, & 3 continuous	Sewage which had been screened (mesh, 37 per inch)	...	...	...
		29 Mar., '00 to 7 July, '00	Ducat	Sewage which had been screened ($\frac{3}{16}$ inch screen) and which had passed through a small grit chamber	...	...	...

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
None ...	...	1	2	1	4	3	2	No. 12 precipitation tank used				
... Lime	...	1	2	1	4	3	2	No. 11 precipitation tank used	82·3	4	80	73·6
None ...	...	1	2	1	4*	3†	2					
*Increased to average of 8 hours during the experimental period.												
...	...	1	2	1	4*	3†	2	...	84	4	80	86
†Reduced to 2 fillings per day during the experimental period.												
None ...	...	1	2	1	8 average	2	2	...	86·6	4	80	86·6
Lime ...	2·8	...	...	...	...	3	2	...	0			
None ...	...	...	...	...	...	...	...	...	92	4	80	87
Lime ...	...	...	2	...	...	3	...	...	77	4	80	62
...	...	...	2	...	...	3	1	...	74	4	80	63
None ...	...	...	...	...	...	$1\frac{1}{3}$	...	...	90	4	80	86
...	...	Continuous method				...	...	...	83 (Purification of septic effluent)	4	80	73
...	...	Continuous method				...	...	...	85 (Purification of septic effluent)	4	80	82
...	...	Continuous method				...	...	...	78	4	80	71
...	...	Working alternate hours for 10 hours, rest 14 hours				...	...	...	91 to 97	4	80	88 to 96

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank.		
				Date.	Gallons.	Percentage of the empty tank.
26	Leeds	No. 1 Coarse bed	174,800	...	83,300	47·7
		No. 3	102,094	...	51,800	50·7
		5	102,094	...	53,100	52·0
		7	177,187	...	55,700	31·4
		8	94,500	...	29,500	31·2

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
2 Dec., '97	63,400	36·3	...	...	19,900	23·9	9 weeks	
16 „ '97	58,800	33·6	...	...	4,600	5·5	2 „	
30 „ '97	57,100	32·7	...	...	1,700	2·0	2 „	
13 Jan., '98	51,100	29·2	...	...	6,000	7·2	2 „	284
27 „ '98	45,400	26·0	...	...	5,700	6·8	2 weeks	
2 Mar., '98	52,100	29·8	...	(increase)	6,700	8·0	...	
14 „ '98	52,300	29·9	...	(increase)	200	0·2	...	
26 „ '98	46,100	26·4	...	...	6,200	7·4	...	
9 April,'98	42,900	24·5	...	...	3,200	3·8	...	
23 „ '98	40,100	22·9	...	...	2,800	3·4	...	
5 May, '98	45,800	26·2	...	7 (increase)	5,700	6·8	...	
20 „ '98	44,300	25·3	...	...	1,500	1·8	...	
2 June, '98	44,600	25·5	...	(increase)	300	0·4	...	315
16 „ '98	43,200	24·7	...	...	1,400	1·7	...	
28 July, '98	56,500	32·3	...	38 (increase)	13,300	16·0	...	
11 Aug., '98	45,800	26·2	...	...	10,700	12·8	...	
25 „ '98	42,400	24·3	...	...	3,400	4·1	...	
8 Sept.,'98	41,000	23·5	...	...	1,400	1·7	...	
18 Nov., '98	42,200	24·1	...	(increase)	1,200	1·4	...	135
7 Oct., '99	26,900	15·4	...	...	15,300	18·4		
1 July, '00	18,200	17·8	...	...	33,600	64·9		
20 „ '00	16,600	16·3	...	...	37,500	70·6		
5 „ '00	25,600	14·5	...	...	30,100	54·0		
1 „ '00	11,000	11·6	...	...	18,500	62·7		

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks.		Capacity of the tanks.
					Area.	Depth.	
					Feet.	Feet.	Gallons.
26	Leeds	7	1	Open	6,000	$7\frac{7}{12}$	250 000
			2	Open	6,000	$7\frac{7}{12}$	250,000
			3	Open	6,000	$7\frac{7}{12}$	250,000
			4, 5, 6, 7	Open	...	...	2,000,000 (total)
		2	Cameron or Exeter	Closed	54 × 10	9	40,000

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used. Weeks.	Rate of flow of sewage through the tank. Gallons per day.	Quantity of sewage passed into the tank. Gallons.	Quantity of sludge left in the tank. Tons.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
			1899						
26	Leeds	1	27 Feb.	...	250,000	134 million gallons	807	82	28
			15 Aug.	...	125,000				
			21 Sept.	...	250,000				
			1900						
			10 Dec.	(End of experiment)					
			1889						
		2	28 April	...	125,000				
			12 May	...	250,000	...	838	80	18
			18 Dec.	...	125,000				
			1900						
			Nov.	(End of experiment)					
			1899						
		3	3 May	...	125,000				
			12 May	...	250,000	...	586	82	23
			18 Dec.	...	500,000				
			1900						
			Nov.	(End of experiment)					
			1889						
		4, 5, 6, 7,	12 June	...	2,000,000	(Tanks working in series)			
			4 Aug.	...	...				
		Closed tanks	6 June	...	40,000				

No.	Name of town or district.	Remarks.
26	Leeds	

PARTICULARS OF THE BACTERIA BEDS, Etc., AT VARIOUS CENTRES.

Table 1.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
27	Leicester	P. T.	4	1 primary ...	...	37 × 30	...	$4\frac{1}{2}$	Clinker, $1\frac{1}{4}$ inch to $2\frac{1}{4}$ inch mesh
				2 ,, ...	...	37 × 30	...	$4\frac{1}{2}$	Clinker, $1\frac{1}{4}$ inch to $2\frac{1}{4}$ inch mesh
				3 ,, ...	...	37 × 30	...	$4\frac{1}{2}$	Clinker, $\frac{3}{4}$ inch to $1\frac{1}{4}$ inch mesh
				4 ,, ...	...	37 × 30	...	$4\frac{1}{2}$	Clinker, $\frac{3}{4}$ inch to $1\frac{1}{4}$ inch mesh
				1 secondary ...	675	...	...	3	Clinker, $\frac{1}{8}$ inch to $\frac{1}{2}$ inch mesh
				2 ,, ...	675	...	...	3	Clinker, $\frac{1}{16}$ inch to $\frac{1}{2}$ inch mesh
									Clinker, $\frac{1}{16}$ inch to $\frac{1}{2}$ inch mesh
									Clay ballast, $\frac{1}{2}$ inch to 1 inch mesh
									Burnt ballast, $\frac{1}{16}$ inch to $\frac{1}{2}$ inch mesh
28	Lincoln	P.	11	1 primary ...	3,255	71 × 50	...	$4\frac{10}{12}$	Broken coke and clinker. Primary beds, $1\frac{1}{2}$ inch mesh. Secondary beds, $\frac{3}{4}$ inch mesh
				2 secondary ...	8,586	159 × 54	...	$4\frac{10}{12}$	
				3 primary ..	3,600	72 × 50	...	$4\frac{10}{12}$	
				4 secondary ...	18,198	182 × 100	...	$5\frac{1}{4}$	
				5 primary ...	3,303	82·5 × 40	...	$4\frac{10}{12}$	
				6 secondary ...	17,280	160 × 108	...	5	
				7 primary ...	2,970	90 × 33	...	$4\frac{10}{12}$	
				9 ,, ...	3,249	79·75 × 40·75	...	$4\frac{1}{3}$	
				11 ,, ...	3,258	78·5 × 41·5	...	$4\frac{1}{3}$	
				13 ,, ...	18,954	189·5 × 100	...	5	
				15 ,, ...	14,301	162·5 × 88	...	$5\frac{1}{4}$	
29	Liverpool (West Derby sewage farm)	P.	6	1 primary ...	...	70·5 × 29·3	...	28	Burnt clay, 3 inch mesh
				1A secondary ...	...	80·6 × 28·3	...	2·6	Coke, 3 inch mesh
									Ballast
				2 primary ...	...	70·5 × 29·3	...	3	Red sandstone, 3 inch mesh
				2A secondary ...	...	80·6 × 28·3	...	3	Coke breeze, small size
				3 primary ...	...	70·5 × 29·3	...	3	Ordinary gas coke, 2 inch mesh
				3A secondary ...	...	80·6 × 28·3	...	3	Sand and gravel

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s d.	£ s. d.	£ s. d.
Two 6 inch layers of old flattened tins, 1 foot apart, were laid in the body of the beds	6 inch and 4 inch land tile drains			
...	3 inch land tile drains			
6 inch... ...	3 inch land tile drains			
19 inch mixed				
11 inch				
Same throughout	Two and three inch pipes leading to each valve. In the large beds there are 4 to 6 valves. The main pipes are provided with branches	...	5,000 – –	– 14 – (labour on beds) – 12 3 (precipitant)
Not graded ...	6 inch main with 3 inch collecting drains			
14 inches				
18 inches				
Not graded				
"				
"				
"				

Table 2.

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks. Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
27	Leicester	24 Oct. to 10 Nov., 1898	1 P	Sewage which had passed through an open detritus tank	18,681	30	...
		11 Nov. to 26 Nov., 1898	1 P	Sewage which had passed through a closed detritus tank	...	(15 feet wide, 7 feet deep)	
		1 Sept. to 10 Nov., 1898	...	Sewage which had passed through an open detritus tank and an open settling tank	...	...	...
		11 Nov. to 6 Dec., 1898	...	Sewage which had passed through a closed detritus tank and an open settling tank	...	...	...
		7 Dec., 1898 to 22 July, 1899	...	Sewage which had passed through a closed detritus tank	...	...	...
		24 July to 15 Sept., 1899	...	Sewage which had passed through a closed detritus tank and a closed septic tank	...	...	...
		19 Sept. to 13 Oct., 1899	...	Sewage which had passed through a closed detritus tank	...	...	...
		28 Nov., 1898 to 19 July, 1899	1 P	Sewage which had passed through a closed detritus tank	...	...	...
		20 July to 2 Sept., 1899	...	Sewage which had passed through a closed detritus tank and closed septic tank	...	...	...
		4 Sept. to 15 Sept., 1899	1 P, 1 and 2 S	Sewage which had passed through a closed detritus tank and closed septic tank	...	...	...
		19 Sept. to 13 Oct., 1899	...	Sewage which had passed through a closed detritus tank	...	...	...
28	Lincoln	...	...	Sewage which had been chemically treated and sedimented (12 hours' settlement)	No detritus tank is used		
29	Liverpool ... ... (West Derby Sewage Farm)	June, 1899, to date	All ...	Crude sewage	No settling tank.		

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
...	...	...	...	...	...	3	1	...	72·7	4	80	72·6
...	...	...	...	...	...	3	1	...	68·9	4	80	74·8
...	...	...	...	...	...	1 & 3	1	...	73·9	4	80	66·6
				(1	filling	daily	for firs	t 12 days only)				
...	...	...	...	...	...	3	1	...	72·6	4	80	81·1
...	...	1	2	2	3	3	1	...	71·2	4	80	71·0
...	...	..	...	...	...	3	1	...	76·2	4	80	65·0
...	...	...	...	...	...	4	1	...	73·5	4	80	73·6
...	...	...	...	...	...	3	2	...	90·2	4	80	83·1
...	...	...	...	...	...	3	2	...	89·7	4	80	79·9
...	...	...	...	...	...	3	3	...	89·6	4	80	83·7
...	...	...	...	...	...	4	3	...	91·3	4	80	86·7
Alumino ferric	3·5	2	2	2	2	3	2	209,234				
None ...	...	$\frac{3}{4}$	2	1	Varies from 2 to 8	1 to 3	2	66,000 (average)				

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank. Date.	Gallons.	Percentage of the empty tank.
27	Leicester	1, 2, 3, 4 P	124,862	24 Sept., '98	61,865	49·5
28	Lincoln	13	591,637	14 Feb., '01	...	...
		...	...	...	...	...
		...	...	...	...	...
		1, 3, 5, 7	404,219 (total)	...	...	...
		...	...	...	...	...
		...	...	...	...	...
		...	...	...	...	...
		15	467,456	27 Nov., '01	193,750	41
		...				
		9 and 11	176,256 (total)			
29	Liverpool ... ... (West Derby Sewage Farm)	1	34,594	28 June, '99	15,575	45·0

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
15 Oct., '98	59,066	47·3	...	...	2,799	4·5	21 days	
21 Dec., '98	49,795	39·9	...	...	9,271	15·0	67 „	
16 Feb., '99	43,211	34·6	...	...	6,584	10·6	57 „	
3 Mar., '99	45,432	36·4	...	3½	2,221 (increase)	3·6	15 „	(7th filling after rest)
29 Mar., '99	43,051	34·5	...	...	2,381	3·8	26 „	
10 April, '99	48,238	38·6	...	10 (increase)	5,187	8·4	12 „	
17 May, '99	41,859	33·5	...	...	6,379	10·3	37 „	
30 May, 99	48,572	38·9	...	12 (increase)	6,713	10·9	13 „	
4 Oct., '99	35,107	28·1	...	...	13,465	21·8	128 „	
6 Nov., '99	44,232	35·4	...	24 (increase)	9,125	14·7	33 „	
6 Nov., '99	40,504	32·4	...	...	3,728	6·0	0 „	(2nd filling after rest)
12 May, '01	217,500	36·8	...	11	...	...	13 weeks	
5 Oct., '01	150,000	25·4	...	7	67,500	...	21 „	
12 Oct., '01	168,750	28·5	...	7 (increase)	18,750	...	1 „	
12 May, '01	127,500	31·5	...	11				
16 Sept., '01	101,250	25·0	...	0	26,250	...	18 „	
1 Oct., '01	120,000	29·7	...	7 (increase)	18,750	...	2 „	
5 Oct., '01	101,250	25·0	...	0	18,750	...	4 days	
3 Mar., '02	160,000	34·2	...	0	33,750	17·4	14 weeks	
5 May, '02	150,000	32·1	...	0	10,000	5·2	9 „	
19 Aug., '01	70,000	39·7	...	0				
21 Nov., '01	55,000	31·2	...	0	15,000	...	13 „	
7 Feb., '02	60,000	34·0	...	9 (increase)	5,000	...	11 „	
12 April, '02	60,000	34·0	...	5	...	...	9 „	
5 May, '02	54,750	31·1	...	0	5,250	...	3 „	
23 April, '00	9,375	27·1	...	0	6,200	39·8	10 months	

Table 4. Particulars of the Septic Tanks (if used).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks. Area. Feet.	Depth. Feet.	Capacity of the tanks. Gallons.
27	Leicester	...	...	Closed	130 × 30	6 to $4\frac{1}{4}$	125,962
28	Lincoln	4	C.D.E.F.	Open	54 × 89	6	180,672 each
		2	A.B.	,,	52 × 23	6·75	54,203 ,,
		1	G.	,,	78 × 89	7	303,712
		1	I.	,,	139 × 46	7·25	313,048
		1	II.	,,	168 × 39	6·5	281,024
29	Liverpool						

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used. Weeks.	Rate of flow of sewage through the tank. Gallons per day.	Quantity of sewage passed into the tank. Gallons.	Quantity of sludge left in the tank. Tons.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
27	Leicester	...	1899 5 June and 13 Oct.	(125 working days)	156,503	...	149	90·77	
28	Lincoln	The tanks are filled and allowed to stand 12 hours, the sewage is then drawn off and the sludge is run into low-lying lagoons and dug in.							
29	Liverpool								

No.	Name of town or district.	Remarks.
27	Leicester	
28	Lincoln	By the end of 1903 it is expected that a sufficient number of bacteria beds will have been constructed to deal with all the sewage, *i.e.*, an ordinary day's supply. There is already sufficient tank accommodation.
29	Liverpool	

PARTICULARS OF THE BACTERIA BEDS Etc., AT VARIOUS CENTRES.

Table 1.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds.	Measurement of the beds.		Depth of the beds.	Material and size of the material of which the beds are composed.
						At top.	At bottom.		
					Square feet.	Feet.	Feet.	Feet.	
30	Manchester	P. T.	1	Roscoe coke	225	12·5 × 18	...	3	Clean washed gravel ...
			1	Roscoe cinder	225	12·5 × 18	...	3	Coke or cinder, $\frac{1}{8}$ inch to $\frac{3}{8}$ inch mesh
									Coke or cinder under $\frac{3}{4}$ inch mesh
									Coke or cinder under $1\frac{1}{2}$ inch mesh
									Rough clinker ... ...
			1	Carbonaceous ironsand	...	...	...	2·5	Ironsand ... ...
									Rubble ... ...
			1	Spent pyrites	225	...	...	3	Burnt pyrites, $\frac{1}{8}$ inch mesh
									Burnt pyrites, 1 inch mesh
									Burnt pyrites, large ...
			1	Fine cinder	...	...	...	2·5	Clinkers, $\frac{1}{8}$ inch mesh ...
									Rubble ... ...
			1	Rough cinder	6048	...	...	$1\frac{1}{4}$	Boiler clinkers ... ...
			1	A	571·6	33·5 × 33·5	17·5 × 17·5	4	Clinker, 1 inch to 3 inch mesh. Afterwards $\frac{3}{4}$ inch to $\frac{1}{8}$ inch mesh
			1	B	571·6	33·5 × 33·5	17·5 × 17·5	4	Clinker, $\frac{1}{4}$ inch to 1 inch mesh
			1	C	571·6	33·5 × 33·5	17·5 × 17·5	4	Clinker, $\frac{1}{4}$ inch to $\frac{3}{4}$ inch mesh
			1	D	571·6	33·5 × 33·5	17·5 × 17·5	4	Clinker, $\frac{1}{8}$ inch to $\frac{1}{2}$ inch mesh
			1	E	56·3	12 × 12	3 × 3	4	Clinker, $\frac{1}{8}$ inch to $\frac{1}{2}$ inch mesh
			1	Stoddart's	144	...	...	6	Coke, 3 inches × 2 inches
									Clinkers, 3 inches × 2 inches
			1	1A	...	165 × 134·25	...	$3\frac{1}{3}$	Clinkers, $\frac{3}{16}$ inch mesh
									Clinkers, large... ...
			1	2A	...	165 × 134·25	...	$3\frac{1}{3}$	
			6	Septic system	294			4	

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
3 inches ...	Open drain pipes and land drain tiles			
6 inches ...				
6 inches				
9 inches				
12 inches				
24 inches				
6 inches				
6 inches				
24 inches				
6 inches				
24 inches				
6 inches				
...	Grips in land filled with bricks			
	The material of this bed was taken out, broken and re-screened in June, 1899.			
...	6 inch and 2 inch pipes in channels in bottom of tanks. Pipes surrounded by coarse material	...	3,350 – –	2 – –
12 inches ...	... ...	17 11 2	(labour)	
5 feet ...	... ...	32 3 4	(material)	
28 inches ...	12 inch pipes in groves in bottom of tanks			
12 inches ...				

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks.		
					Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
30	Manchester ...	1898 1 Jan., 15 Dec.	Roscoe	"Chemical" effluent...	...	...	...
		16 Dec. ...	,,	,, ,, ...	...	...	...
		1900 29 Mar, 30 May	,,	,, ,, ...	...	...	...
		1900 1901 31 May 20 Feb.	,,	,, ,, ...	...	...	...
		1901 28 Feb., 27 Mar.	,,	,, ,, ...	...	...	...
		1901 1902 27 Mar., 26 Mar.	,,	,, ,, ...	...	...	...
		20 Nov., 1898, 29 April, 1899	6 septic beds	Septic sewage...	...	...	...
		1898 17–21 Sept. ...	A and B	Settled sewage	...	...	...
		30 Sept., 26 Oct.	,,	,, ,, ...	...	...	...
		28 Oct., 16 Nov.	,,	,, ,, ...	...	...	...
		17 Nov., 3 Dec.	,,	,, ,, (two fillngs) and raw sewage (one filling)	...	...	...
		3 Dec., 14 Dec.	A B and E	Settled sewage (two fillings) and raw sewage (one filling)	...	...	...
		16 Dec., 1898, 7 Feb., 1899	,,	Raw sewage	...	...	...
		1899 9 Feb., 1 May	,,	,, ,, ...	...	...	...
		13 April, 31 May	C and D	Settled sewage and occasional fillings of storm water	...	...	...
		1 June, 7 June	,,	Open septic tank sewage	...	...	...
		8 June, 5 July	,,	,, ,, ...	...	...	...
		6 July, 17 Aug.	,,	,, ,, ...	...	...	...
		18 Aug., 14 Sept.	C	,, ,, ...	...	...	...
			B and D	Effluent from primary bed C divided between these beds	...	...	...
		4 Oct., 7 Dec.	A and C	Open septic tank sewage	...	...	...
			D	Effluent from primary beds A and C run on to bed D	...	...	...
		22 Aug., 31 Aug.	A	Open septic tank sewage	...	...	...
		1 Sept., 15 Sept.	,,	,, ,, ...	...	...	...
		16 Sept. ...	,,	,, ,, ...	...	...	...
		1899 1900 7 Dec. 11 Apr.	A and C	,, ,, ...	...	...	...
			D	Effluent from primary beds A and C ...	...	...	...
		1900 3-30 May ...	A and C	Settled sewage	...	...	...
			D	Effluent from primary beds A and C ...	...	...	...
		31 May, 1900, 27 Mar., 1901	A and C	Settled sewage	...	...	...
			D	Effluent from primary beds A and C ...	...	...	...
		1899 1900 7 Dec. 22 Feb.	B	Open septic tank sewage	...	...	...
		1900 2 Mar., 25 April	,,	,, ,, ...	...	...	...
		8 May, 7 June	,,	,, ,, ...	...	...	...
		1900 1902 15 June 26 Mar.	,,	,, ,, ...	...	...	...
		1900 1901 11 Jan. 17 July	Iron sand bed	"Chemical" effluent	...	...	...
		1900 22 March ...	Fine cinder	,, ,, ...	...	...	...
		1899 29 June ...	Rough cinder	,, ,, ...	...	...	...
		1900 29 Mar., 30 May	,,	,, ,, and storm water ...	...	...	...
		1900 1902 13 June 26 Mar.	,,	,, ,, ,, ...	...	...	...
		1900 8 Aug. ...	Stoddart's	Open septic tank effluent	...	...	...
		1900 1901 25 Aug. 17 Jan.	Burnt pyrites	"Chemical" effluent...	...	...	...
		1901 18 Jan. ...	,,	,, ,, ...	...	...	...
		28 Jan., 17 Apr.	1a 2a	Open septic tank effluent	...	...	...

Chemicals used for treating the sewage previous to bacterial treatment: Name of chemical.	Grains per gallon of sewage.	Number of hours: Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).	Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison. Gallons.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of Oxygen absorbed by the crude sewage and by the final bacteria bed effluent: Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Lime	2·17	½	2	½	...	3	1	205,840				
Sulphate of iron	1·17	...	...	...	...	4	1	208,120				
	...	...	...	...	...	4	1					
	...	...	...	...	...	3	1		58·7 (coke)	4	...	58·1
	...	...	...	...	...	2	1					
	...	...	...	...	...	3	...	157,000	68·3 (cinder	4	...	67 1
	...	...	...	...	...	1 & 2	1	165,000				
...	...	...	...	...	...	1	2					
...	...	...	...	...	...	2	2					
...	...	...	..	...	...	3	2					
...	...	...	...	...	...	3	2					
...	...	...	...	...	...	3	3					
...	...	...	...	...	...	3	3					
...	...	...	...	...	...	4	3					
...	...	...	...	...	...	2	2					
...	...	...	...	...	...	2	2					
...	...	...	...	...	...	3	2					
...	...	...	...	...	...	4	2					
...	...	...	...	...	...	8	2					
...	...	...	...	...	...	4	2					
...	...	...	...	...	...	8	2					
...	...	...	...	...	...	4	2					
...	...	...	...	...	...	2	1					
...	...	...	...	...	...	3	1					
...	...	.	...	...	...	4	1					
...	...	...	continuous on D			...	1					
...	...	...	continuous on D			...	2					
...	...	...	...	...	...	2	2					
...	...	...	...	...	...	4	2					
...	...	...	...	...	...	3	2					
...	...	...	...	...	...	6	2					
...	...	...	...	...	...	4	1					
...	...	continuous equal to				6	1					
...	...	...	...	...	...	2	1					
...	...	...	...	...	...	3	1					
Lime	2·17	...	...	...	...	3	1		90.1	4	...	84·5
Sulphate of iron	1·17	...	...	...	...	3	1	166,496	85·3	4	...	82·6
	...	...	...	...	...	...	...					
	...	...	...	...	...	4	1		59·1	4	...	53·5
	...	...	continuous									
...	...	...	continuous									
...	‥	...	...	...	...	2	1	112,933				
...	...	...	...	...	...	3	1					
...	...	...	...	...	...	1	1					

Table 3.

PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank. Date.	Gallons.	Percentage of the empty tank.
30	Manchester	Roscoe coke	...	15 Dec., '95	1,750	...
				(Bed had been washed)		
		„ cinder	...	15 Dec., '95	1,750	...
				(Bed had been washed)		
		A	10,580	27 Oct., '98	4.800	45
		B	10,580	10 Sept., '98	5,004	47
		C	10,580	11 April, '99	5,000	47

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
5 Jan., '98	1,260	...	2	...	490	28	2 years	
7 Jan., '01	1,008	...	...	1	258	15	3 ,,	
17 Jan., '01	1,166	...	2½		(increase) 158	9	10 days	
26 Mar., '02	1,008	...	10½	...	258	15	15 months	
5 Jan., '98	1,330	...	2	...	420	24	2 ,,	
7 Jan., '01	1,080	...	...	1	250	14	5 ,,	
25 Jan., '01	1,224	...	2½		(increase) 164	9	5 ,,	
26 Mar., '02	1,044	...	10½	...	180	10	...	
15 Nov., '98	4,530	43	3	...	270	6	19 days	
20 April, '99	3,350	32	2½	7	1,180	25	25 weeks	
20 Sep., '99	3,930	37	4½		(increase) 580	12	47 ,,	
21 Sep., '99	3,520	33	1¼	...	410	9	47 ,,	
22 Dec., '99	2,860	27	3	...	660	14	60 ,,	
5 July, '00	2,660	25	...	7	200	4	98 ,,	
6 July, '00	2,280	22	7½	...	380	8	98 ,,	
25 Feb., '01	2,440	23	...	2	(increase) 160	3	131 ,,	
20 Mar., '02	2,210	21	10½	...	230	5	...	
16 Nov., '98	4,530	43	3	...	474	9	10 ,,	
20 April, '99	4,350	41	2½	7	180	4	32 ,,	
22 Sep., '99	4,470	42	3½		(increase) 120	2	54 ,,	
2 Aug., '00	2,980	28	1¼	...	1,490	30	47 ,,	
24 Jan., '01	3,110	29	...	7	(increase) 130	3	123 ,,	
22 Mar., '01	2,600	25	1¼	...	510	10	133 ,,	
8 April, '02	2,730	26	11		(increase) 130	3	...	
5 July, '99	3,690	35	4	...	1,310	26	12 ,,	
14 Sep., '99	1,965	19	1½	...	1,725	34	23 ,,	
15 Sep., '99	2,220	21	3½		(increase) 255	5	23 ,,	
26 Sep., '99	3,520	33	...	11	(increase) 1,300	26	25 ,,	
1 June, '00	2,580	24	6	...	940	19	59 ,,	
23 Aug., '00	3,100	29	...	7	(increase) 520	10	71 ,,	
14 Mar., '01	2,580	24	...	7	520	10	100 ,,	
15 Mar., '01	2,230	21	7	...	350	7	100 ,,	
3 April, '02	2,250	21	10¼		(increase) 20	4	...	

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks. Area.	Depth.	Capacity of the tanks.
					Feet.	Feet.	Gallons.
30	Manchester	1	...	Closed	40 × 12	$9\frac{1}{6}$	27,500
		2	...	Open	300 × 100	6	1,125,000
		The open septic tanks have been recently enlarged as follows—			300 × 100	7	1,300,000

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
30	Manchester	1	16 Feb., '99 to 26 April, '00	...	4,200,000	...	4,000	85	75
			16 May, '00 to 14 Nov., '00	...	2,500,000	425,000,000	...	...	21·6
			14 Nov., '00 to 24 Jan., '01	...	2,000,000	142,000,000	...	...	33·5
									50·0 (estimated)

No.	Name of town or district.	Remarks.
30	Manchester	The sewage before treatment of any kind, is screened by a bar screen of ½ inch mesh, but since October, 1899, unscreened sewage has been supplied to the septic tanks. There are now at Manchester 12 half-acre beds in regular operation and many more are in course of construction.

PARTICULARS OF THE BACTERIA BEDS, &c.,
AT VARIOUS CENTRES.

Table 1. PARTICULARS OF THE

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds.	Measurement of the beds.		Depth of the beds.	Material and size of the material of which the beds are composed.
						At top.	At bottom.		
					Square feet.	Feet.	Feet.	Feet.	
31	Middleton	P.	2	1 and 2	22,230	62·5	59·5	3	Clean riddled mill cinders 1 inch mesh 3 inch mesh
32	Nelson	P.	6	1 Primary	49,600 (total)	116 × 80	113 × 77	3	Coarse clinkers
				2 ,,		93 × 80	90 × 80	3	
				3 ,,		116 × 80	113 × 80	3	
				4 ,,		93 × 80	90 × 80	3	
				5 ,,		116 × 85	113 × 82	3	
				6 ,,		86 × 85	83 × 82	3	
33	Oldham	P.	...	1	...	118 × 89	...	$2\frac{3}{4}$	Screened furnace ashes
				2	...	139 × 89	...	$2\frac{3}{4}$	,, about $\frac{1}{4}$ inch mesh
				3	...	139 × 89	...	$2\frac{1}{4}$	,, ,,
				4	...	139 × 89	...	$2\frac{1}{2}$	,, ,,
				5	...	$157\frac{1}{2} \times 93\frac{1}{2}$	...	$2\frac{1}{4}$	,, ,,
				6	...	$155\frac{1}{3} \times 89\frac{1}{2}$	...	$2\frac{1}{4}$	,, ,,
				7	...	$155\frac{1}{3} \times 89\frac{1}{2}$	...	$2\frac{1}{4}$	,, ,,
				8	...	$132 \times 101\frac{3}{4}$	...	2	,, ,,
				9	...	$132 \times 100\frac{1}{2}$	...	$1\frac{3}{4}$	,, ,,
				10	...	161 × 17	...	$2\frac{1}{4}$	,, ,,
				11	...	161 × 68	...	2	,, ,,
				12	13,338	...	...	$2\frac{1}{2}$	,, ,,
				13	...	145 × 95	...	3	,, ,,
				14	...	$136 \times 95\frac{1}{2}$	...	3	,, ,,
				15	...	...	...	3	Crushed and screened clinker from refuse destructor
				16	...	...	...	3	
				18	...	...	...	3	
34	Ormskirk	P.	3	...	2,400 (each)	...	...	3·5	Coke breeze ... ...
35	Oswestry	P.	9	Primary	...	60 × 60	51 × 51	$4\frac{1}{2}$	Cinders, $\frac{3}{8}$ inch to $1\frac{1}{2}$ inch mesh
			9	Secondary	...	60 × 50	51 × 41	$4\frac{1}{2}$	Cinders, $\frac{3}{8}$ inch to 1 inch mesh
36	Oldbury...	—	4	Primary	50,535 (total)	...	...	3·25	$1\frac{3}{4}$ inch to $\frac{5}{8}$ inch mesh
			18	Secondary	29,943 (total)	...	...	3·25	$1\frac{1}{8}$ inch to $\frac{3}{8}$ inch mesh

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
2 feet 6 inches 6 inches	9-inch central drain and 4-inch unsocketed perforated drain pipes arranged herring bone fashion	1,145 – –	2,290 – –	2 10 $2\frac{1}{4}$
One grade only	Earthenware pipes	...	3,000 – –	
Material is not graded in the beds, but larger pieces have been arranged round under-drains	... ...	...	...	1 16 11
...	Mains E.S.P. Wing dains 4 inch land tiles	60 – –	1,089 – –	
Not graded ...	3-inch agricultural drain pipes lead-into brick channels	2,100 – – Cost of permanent works	1,615 – –	1 12 6 (including sludge disposal)

Table 2. PARTICULARS AS TO THE WORKING

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks.		
					Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
31	Middleton	Commenced 29 Nov., '99 26 Jan., '00	1 2	Tank effluent from sewage which has passed through a grit chamber, and then been treated with chemicals and sedimented	120,000	24 in diameter	1,000,000
32	Nelson	11 months 3 years ... $2\frac{1}{2}$ years ... 10 months 16 months $2\frac{1}{2}$ weeks ..	1 2 3 4 5 6	Tank effluent	1,050,000	10 each 100 × 30	600,000 (dry weather flow)
33	Oldham	1897 to end of 1898	...	Effluent from chemically treated and sedimented sewage	2,116,800 (total of 12 tanks)	128	...
		1899 to date	...	Effluent from sewage after subsidence ...	(Each of 2 detritus tanks)	45	22,500
			12 and 13	Settling tank liquid drawn off by floating arms previous to cleaning tank	...	...	...
34	Ormskirk	...	...	Sewage after having gone through process of land filtration	83,000 (8 tanks total)	...	...
35	Oswestry	...	Primary Secondary	Settling tank liquid ... ... Effluent from primary beds.	56,000 (total)	70	29,531
36	Oldbury	...	Primary Secondary	Chemically treated and sedimented sewage	...	...	...

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
Ferozone	6	...	3	...	3	...	...	...	90·0			
Alumino ferric	9	½ (about)	...	...	...	6		...	...	...	...	71·4
Sulphate of iron Lime ...	1 4	½ to ⅔	2 to 3	2	2 (at least)	2 (Sundays included)	...	161,000 (about)	79·1	4	...	82·1
...	...	...	...	...	...	...	...	...	84·1	4	...	84·3
...	...	...	4 to 24									
...	...	...	...	...	...	...	...	110,083 110,195	88·2	...	...	89·7
...	...	½ to 1¼ 1 to 1½	1 to 2½ 3 to 4	¾ 1	2 to 5 3 to 4½	2 to 5 2	... 2	100,000 ...	88·2	0·3	140	89·7
...	...	...	2 2	...	...	2 3						

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank. Date.	Gallons.	Percentage of the empty tank.
31	Middleton	1 and 2	...	...	...	...
32	Nelson	1	168,188			
		2	138,000			
		3	172,500			
		4	138,000			
		5	181,125			
		6	132,281			
33	Oldham	1				
		2				
		3				
		4				
		5				
		6				
		7				
		8				
		9	...	...	...	40 per cent.
		10				
		11				
		13				
		14				
34	Ormskirk ...					
35	Oswestry	...	...	...	...	...
36	Oldbury...	...	315,844 (total) 187,144 (total)			

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
...	1,700,000 One bed only							
10 Feb, '02	33,870	20·1	...	½			11 months	
11 ,,	21,540	15·6					3 years	
12 ,,	22,170	12·9					2½ ,,	
13 ,,	35,920	26·0					10 months	
25 ,,	37,330	20·6					16 ,,	
26 ,,	59,170	44·7					2½ weeks	
1900	60,121							
,,	70,138							
,,	57,382							
,,	63,762							
,,	73,361							
,,	69,520							
,,	69,520							
,,	58,183							
,,	58,038							
,,	53,000							
,,	54,740							
,,	71,150							
,,	70,550							
			(Primary beds)			30 to 40	3 to 4 years	

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks.		Capacity of the tanks.
					Area.	Depth.	
					Feet.	Feet.	Gallons.
31	Middleton						
32	Nelson	Septic tank only just started.					
33	Oldham	1	...	Open	...	7·5	175,400
34	Ormskirk ...						
35	Owestry...						
36	Oldbury...						

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
31	Middleton								
32	Nelson								
33	Oldham		June, 1900 to June, 1901	52 weeks	350,000	127,750,000	(2 feet deep)		
34	Ormskirk								
35	Oswestry								
36	Oldbury...								

No.	Name of town or district.	Remarks.
31	Middleton	If sufficient area of beds is employed and they are properly managed the treatment is satisfactory. It is contemplated treating the whole of the sewage by the bacterial process.
32	Nelson	Results obtained by experimental beds are quite satisfactory.
33	Oldham	Average daily flow of sewage (1900) 4,000,000 gallons. Experiments show that bacteria beds should be supplied with a tank effluent of uniform strength. Chemicals are an unnecessary expense and rather hinder the work of the bacteria beds than assist it. It is intended to treat the Oldham sewage by subsidence followed by the action of bacteria beds. There is a greater uniformity in the strength of the effluent from the septic tank than in that from the sedimentation tanks, and the bacteria beds act better when an effluent of uniform strength is used, and the effluent from the septic tank and bacteria beds seldom putrifies on incubation. There is also a very considerable reduction in the quantity of sludge.
34	Ormskirk	The results obtained at the farm of the Urban District Council of Ormskirk by passing the sewage through lagoons, into settling tanks, over the land and through the coke breeze filter beds successively, are very satisfactory and meet the requirements of the authorities (no chemicals are used).
35	Oswestry	Small experimental beds were originally constructed. Later, beds for the treatment of the whole of the sewage. There is no doubt as to the success of the bacterial treatment, our results are continuously satisfactory and the effluents keep free from putrescence. Probably a small amount of septic action takes place in the settling tanks.
35	Oldbury...	

PARTICULARS OF THE BACTERIA BEDS, Etc., AT VARIOUS CENTRES.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
37	Reigate	T.	1	Primary coarse	450	21 ft. 3 in. (square)	...	3·5	Broken bricks, coke and cinder, 3 inch to $1\frac{1}{2}$ inch mesh $1\frac{1}{2}$ inch to $\frac{3}{4}$ inch mesh $\frac{1}{2}$ inch to $\frac{1}{12}$ inch mesh
			1	Secondary fine	450	24 ft. dia. (circular)	...	3·5	Broken bricks and coke $\frac{1}{2}$ inch to $\frac{1}{12}$ inch mesh $\frac{1}{2}$ inch to $\frac{3}{16}$ inch mesh Polarited clinkers, $\frac{1}{2}$ inch to $\frac{3}{16}$ inch mesh
38	Rochdale	T.	2	...	1,800 (each)	48 (in diameter)	...	9	Gas coke above $1\frac{1}{2}$ inch mesh
39	Salford	P.	...	Roughing beds	...	...	...	3	Gravel (fine) ... ...
		T.	14	...	126	...	...	5 and 8	Cinder, between 6-wire mesh and 2-wire mesh to inch
40	Sheffield	T.	3	1, 2, 3 1st contact ...	45,000 (total of 3)	...	...	5	Coke ... ...
			3	1, 2, 3 2nd contact ...	40,500 (total of 3)	...	...	$3\frac{1}{3}$	Coke ... ...
41	Southport	T.	2	Coarse	900 (each)	30 × 30	24 × 24	3	Coke, $\frac{1}{2}$ inch mesh ...
			1	Fine	900	30 × 30	24 × 24	3	Coke, $\frac{3}{8}$ inch mesh ...
42	Swinton and Pentlebury	P.	10	Primary ...	...	75 × 75	...	3·25	Rough clinkers... ... Cinders above $\frac{1}{2}$ inch mesh
			10	Secondary ...	...	75 × 75	...	...	Cinders above $\frac{3}{4}$ inch mesh Cinders $\frac{1}{8}$ inch to $\frac{3}{8}$ inch mesh
43	Wolverhampton ...	T. P.	2	1	810	...	...	4·25	Slack ... ...
				2	4,500			4·25	Furnace ashes, $\frac{3}{16}$ in. to $1\frac{1}{2}$ in. mesh
44	Wednesbury	T.	1	Primary ...	...	...	...	3	Furnace clinkers, 2 inch to 1 inch mesh Furnace clinkers, $\frac{3}{4}$ inch to $\frac{5}{8}$ inch mesh Furnace clinkers, $\frac{1}{2}$ inch to $\frac{1}{4}$ inch mesh
		...	1	Secondary ..	...	...	...	5	Coal, $\frac{3}{4}$ inch mesh ... Coal, $\frac{1}{2}$ inch mesh ... Coal, $\frac{3}{8}$ inch to $\frac{1}{4}$ in mesh Coal, $\frac{3}{16}$ inch to $\frac{1}{16}$ inch mesh Fine dust ... ...
		...	1	Secondary ...	...	...	...	5	Granite, same size as coal bed
45	West Bromwich ...	P.	1	Single contract	2,520	60 × 42	...	3	Engine ashes, $\frac{1}{2}$ inch to 2 inch mesh
			1	Primary ...	7,200	120 × 60	...	3·5	Engine ashes, $\frac{1}{2}$ inch to 2 inch mesh
			1	Secondary ...	7,200	120 × 60	...	3	Engine ashes, $\frac{1}{8}$ inch to $\frac{1}{2}$ inch mesh
46	Worcester	...	3	...	...	80 × 3	...	2	Furnace ashes, 1 inch to $\frac{1}{20}$ inch

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
1 foot 6 inches 1 ,, 6 ..	Agricultural tiles			
6 ,, 9 ,, 9 ,, 1 ,, 6 ,,	Bricks laid as stretchers with headers above ½ inch open joints			
Uniform throughout	Perforated semi-circular 18 inch pipes laid on bricks on a concrete floor		5,000 – – (about) for construction of beds and coke only	4 – – estimated
...	...	...	7,000 – –	– 16 – (exclusive of chemical precipitation and pumping)
Uniform	By 6 inch open jointed earthenware pipes	250 – – (approximately)	...	...
12 inch 9 inch 6 inch 12 inch				
Uniform	6 inch channels covered with perforated inverts	...	3,000 – –	
24 inch 6 inch 6 inch 3 inch 3 inch 24 inch 24 inch 6 inch				
Not graded	No under drains in any of the beds. Valves fixed at the side for emptying	400 – – 600 – – 600 – –		
	No under drains			

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks. Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
37	Reigate	3 years ...	1 and 2	The sewage contains large quantities of brewery and tannery refuse	... (Two 3·5 × 4 × 8 feet)	8	18,000
38	Rochdale	2½ years ...	1 and 2	Sewage after passing through open septic tank	200,000	160	160,000
39	Salford	...	...	Sewage from which road detritus etc., has been removed in "silt pits," and which has passed through precipitation tanks	5,250,000 (total of 12 tanks)	110 (each)	12,000,000 (average)
40	Sheffield	3 years ...	...	Sewage which has rapidly passed over two catch pits (the heavier detritus separates fairly readily, but finely divided mineral matter remains mixed with putrescible solids)	...	...	...
41	Southport	...	...	Screened sewage	...	...	...
42	Swinton and Pentlebury	...	...	Screened and chemically treated and precipitated sewage	...	...	...
43	Wolverhampton ...	...	...	Tank effluent after lime treatment. It was possible to only partially separate out road detritus	...	...	...
44	Wednesbury	...	Primary	Septic tank effluent	...	...	...
			Secondary	... ...	...	...	...
			Secondary	... ...	...	...	...
45	West Bromwich ..	12 Sept., '99 to 1 Nov., '00	Single contract	Effluent from septic tank	50,000	40	...
		3 Oct., '99 to 1 Nov., '00	Primary Secondary	Crude sewage	...	...	...
46	Worcester	...	...	Domestic sewage from isolation hospital ...	...	...	...

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
None used	...	...	...	...	...	...	2	...	81	4	55	87
None ...	...	continuous process			...	...	...	215,111	84·0	4	57 to 63	84·2
Lime ...	13	continuous method by spray jets					2	2,500,000 to 7,000,000 5 to 8 feet deep				
...	...	1	1	2	4	3	2	200,000 (in first contact beds) 195,000 (in second contact beds)	87 to 90	4	Laboratory temperature	92·0 (about)
...	...	1	2	1	2	4	2	295,000	79·8	4	80	
								Average of 3 samples June & July, 1900				
Lime Sulphate of iron	...	...	1½	...	...	3	2	...				
Lime	...	1½	2	1½	7	1 & 2	...	200,000 (Bed No. 1 two fillings) 123,000 (Bed No. 2 two fillings)	83·5 on tank effluent			
...	...	...	2	...	...	3	2					
...	...	continuous process			...	...	...		86·0	4	80	
...	...	...	...	...	...	...	...		87·7	4	80	
...	...	1½	2	1½	3	3	1	...	57	4	...	54·7
None ...	...	1½	2	1½	3	3	2	...	85·9	4	...	78·6
None ...	...	...	...	...	...	...	...	...	97·7	4	...	95·2

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank. Date.	Gallons.	Percentage of the empty tank.
37	Reigate					
38	Rochdale	No loss of capacity detected.				
39	Salford					
40	Sheffield					
41	Southport	Coarse and fine	16,875	...	7,500 (each)	44·4
42	Swinton and Pentlebury					
43	Wolverhampton ...					
44	Wednesbury	Primary Secondary	...	...	15,000 35	
45	West Bromwich ...	Single contact Primary Secondary	47,250 157,500 135,300	... ...	16,666 45,000 45,000	35·3 28·6 33·3
46	Worcester	No measurements as to capacity have been made.				

Beds and as to the loss of Capacity during working.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
...	9,950	21·1	...	...	6,716	40·2	...	816
...	29,455	18·7	...	...	15,545	34·5	12 months	...
...	33,337	24·6	...	...	11,663	25·9	12 months	...

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks. Area.	Depth.	Capacity of the tanks.
					Feet.	Feet.	Gallons.
37	Reigate						
38	Rochdale	1	...	open	6,400	5	200,000
39	Salford						
40	Sheffield						
41	Southport						
42	Swinton and Pentlebury						
43	Wolverhampton ...	1	...	open	7,500	5·3 (mean)	249,000
44	Wednesbury	1 2	... ...	covered open			
45	West Bromwich ...	2	...	open	800	5	25,000 (each)
46	Worcester						

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used. Weeks.	Rate of flow of sewage through the tank. Gallons per day.	Quantity of sewage passed into the tank. Gallons.	Quantity of sludge left in the tank. Tons.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
37	Reigate								
38	Rochdale	1		2 years	200,000 (3 months) 160,000 (afterwards)	130,000,000	200 of pressed sludge of 60 per cent. moisture	89·8	26·5 (total solids) 62·0 (suspended solids)
39	Salford								
40	Sheffield...								
41	Southport								
42	Swinton and Pentlebury								
43	Wolverhampton ...	1	31 May, '99, to 16 Oct., '00	68	250,000 (average) 50,000 to 500,000	...	...	...	33·0
44	Wednesbury								
45	West Bromwich ...								
46	Worcester								

No.	Name of town or district.	Remarks.
37	Reigate	The sewage is distributed evenly over the surface of the bed by the automatic Candy-Caink sprinkler fed by intermittent valves. Two or three minutes flow of sewage is held up in a storage chamber and then discharged through the sprinkler in about one minute so that the bed is in this way both worked and rested in an intermittently continuous manner. There is no water logging of the bed and that continuous and frequent aëration is insured, is shown by the effluent being practically saturated with dissolved oxygen.
38	Rochdale	The two beds are Whittaker and Bryant's thermal aërobic filters (as at Accrington). The sewage passes through a septic tank of a capacity of $1\frac{1}{4}$ days flow. The sewage from the open septic tank flows into a small tank and is then pumped up and continuously and evenly distributed over the surface of the two beds by automatically revolving sprinklers, and passes directly through the bed. The septic tank was in use too long without the sludge being cleaned out. It will be cleaned out more frequently in future.
39	Salford	Clarified sewage from the precipitation tanks which had passed through a roughing gravel filter was supplied to the bed by sprinkler jets making a spray or rainfall over the surface of the bed. Thus clarified sewage and air passed continuously through the filters while they were working. The roughing beds intercepted a good deal of fine mud and required cleaning out about every second day. We can fully depend upon the bacteria beds to give a satisfactory effluent even when working night and day almost without intermission.
40	Sheffield	The degree of purification obtained has been uniformly satisfactory. The loss of capacity of the beds continues and experiments are being conducted with the object of reducing this as much as possible. Permanent works on bacterial principles are contemplated, but working details cannot be decided upon until further experiments are completed.
41	Southport	Only a small proportion of the sewage is treated. The beds have always worked to entire satisfaction, and they have always produced a clear and non-putrescible effluent.
42	Swinton and Pentlebury	The information respecting this centre has been obtained from the particulars published by the Borough of Walsall.
43	Wolverhampton ...	The results from No. 1 bed were good, but, owing to the presence of iron salts in the sewage, a permanent installation is doubtful. It was necessary on account of the iron salts to add lime to the sewage before it passed into the septic tank.
44	Wednesbury	
45	West Bromwich ...	
46	Worcester	These beds are in use only at the Isolation Hospital. They consist of trenches filled with furnace ashes along which the sewage flows.

PARTICULARS OF THE BACTERIA BEDS, Etc., AT VARIOUS CENTRES.

No.	Name of town or district.	Nature of installation. P.—Permanent. T.—Temporary.	Number of beds.	Distinctive number or name of each bed.	Average or working area of the beds. Square feet.	Measurement of the beds. At top. Feet.	Measurement of the beds. At bottom. Feet.	Depth of the beds. Feet.	Material and size of the material of which the beds are composed.
47	York	T	4	1	800	40 × 20	...	3	Clinker, cinder and coke, $\frac{3}{8}$ inch to $1\frac{1}{4}$ inch mesh
				2	800	40 × 20	...	3	
				3	800	40 × 20	...	3	
				4	800	40 × 20	...	3	
		T	2	1A	...	90 × 30	...	2·75	Clinker, cinder and coke, $1\frac{1}{4}$ inch to 3 inch mesh
				2A	...	90 × 30	...	2·75	Clinker, cinder and coke, $\frac{3}{8}$ inch to $\frac{3}{4}$ inch mesh
		T	1	Ladder filter composed of 10 chambers		4 × $3\frac{5}{12}$	...	2	Clinker
		T	1	York filter ...	...	67·5 in diameter	...	6·5	Clinker, $\frac{1}{2}$ inch to $2\frac{1}{2}$ inch mesh
		T	1	Gravel	...	$19\frac{1}{3}$ × $11\frac{1}{4}$	...	3	Clean gravel, coarse ...
									,, $\frac{3}{8}$ inch mesh
									,, $\frac{1}{2}$ inch ,,
									,, $\frac{3}{4}$ inch ,,
									,, $1\frac{1}{2}$ inch ,,

BACTERIA BEDS.

Thickness of each layer of material, arranged in their order in the beds, from the top downwards.	Method of under-draining the beds.	Actual or estimated cost of making the beds.	Actual or estimated cost per acre of making the beds.	Cost of treating sewage per million gallons.
		£ s. d.	£ s. d.	£ s. d.
3 layers, the largest material at the bottom.				
Layers of coarser material at the top				
4½ inches 4½ inches 9 inches 9 inches 9 inches				

Table 2. PARTICULARS AS TO THE WORKIN

No.	Name of town or district.	Time during which the beds were in use.	Name or number of the bed used.	Character of the liquid supplied to the beds.	Particulars of the settling and of the detritus tanks.		
					Capacity. Gallons.	Length. Feet.	Rate of flow of sewage through the tanks. Gallons per day.
47	York	21 April, 1899 to 31 Aug., 1901	1, 2, 3, 4	Closed septic tank effluent	...	...	...
		13 June, 1899 to 13 Oct., 1900	1a, 2a	Crude sewage which had been screened ...	...	...	...
		8 June, 1899 to 15 Sept., 1900	Ladder filter (10 chambers in series later, 2 sets of 5 chambers in series)	Raw sewage	...	...	...
		5 July, 1900 to 12 Mar., 1900	York filter	Open septic tank effluent	...	...	...
		23 Nov., 1900 to 1 July, 1901	1a, 2a	Open septic tank effluent	...	...	...
		14 June, 1899	1, 2, 3, 4	Closed septic tank effluent (finally treated on land filters)	...	...	...
			Gravel	Open septic tank effluent (not satisfactory)	...	...	...

OF THE BACTERIA BEDS.

Chemicals used for treating the sewage previous to bacterial treatment.		Number of hours				Number of fillings per 24 hours.	Number of contacts in successive beds.	Quantity of sewage treated in 24 hours, per acre of bed, one foot deep. Calculated for the purpose of comparison.	Average percentage purification effected on the crude sewage, as measured by the relative quantities of			
									Oxygen absorbed by the crude sewage and by the final bacteria bed effluent.			Albuminoid ammonia present in the crude sewage and in the final bacteria bed effluent.
Name of chemical.	Grains per gallon of sewage.	Occupied in filling the beds.	During which the beds remained full (contact period).	Occupied in emptying the beds.	During which the beds remained empty (aëration period).			Gallons.	Average percentage purification.	Number of hours occupied in absorption.	Temperature at which absorption took place ° F.	
...	...	$1\frac{1}{2}$ to 2 vari	2 able	4 to $4\frac{1}{2}$		2 & 3	1	69,193 and 196,085	65·47	4	80	61·97
...	...	var	ied	...	...	3	2	55,569	80·0	4	80	72·0
...	...	...	...	...	...	...	...	175,368	44·3	4	80	36·6
...	...	co	ntinuo	us proc	ess	...	...	327,631	84·5	4	80	90·0
...	...	$1\frac{1}{2}$	$1\frac{1}{2}$	2	3	3	1	65,200	78·6	4	80	87·6

Table 3. PARTICULARS AS TO THE CAPACITY OF THE BACTERIA

No.	Name of town or district.	Name or number of bed.	Capacity, when empty, of the tank containing the bed. Gallons.	Original water capacity of the bed in the tank. Date.	Gallons.	Percentage of the empty tank.
47	York	1A	46,406	13 June, '99	18,550	40
		2A	No appreciable	reduction of	this bed was	observed.

BEDS AND AS TO THE LOSS OF CAPACITY DURING WORKING.

Water capacity of the bed after use.			Number of hours occupied in draining the bed.	Number of days during which the bed had been resting previous to the measurement being made.	Loss of capacity.		Length of time during which the bed was in use.	Number of fillings during the time.
Date.	Gallons.	Percentage of the empty tank.			Gallons.	Percentage of original water capacity of the bed.		
11 Sept.,'99	9,300	20·2	...	...	9,250	50	90 days	200
25 Sept.,'99	13,650	29·7	...	14	(increase) 4,350	23	14 ,,	
6 Nov., '99	9,600	20·9	...	...	4,050	22	43 ,,	

Table 4. PARTICULARS OF THE SEPTIC TANKS (IF USED).

No.	Name of town or district.	Number of tanks.	Distinctive name or number of each tank.	Whether the tanks are open or closed.	Dimensions of the tanks.		Capacity of the tanks.
					Area.	Depth.	
					Feet.	Feet.	Gallons.
47	York	1	...	Closed	800	8	40,000
		1	...	Open	6,400	6·25	250,000

Table 5. PARTICULARS AS TO THE WORKING OF THE SEPTIC TANKS.

No.	Name of town or district.	Name or number of tank.	Dates between which the tank was in use.	Length of time during which the tank was used.	Rate of flow of sewage through the tank.	Quantity of sewage passed into the tank.	Quantity of sludge left in the tank.	Percentage of moisture in the sludge left in the tank.	Percentage reduction in the amount of sludge effected by septic action.
				Weeks.	Gallons per day.	Gallons.	Tons.		
47	York	Closed	21 April, 1889 to 31 Aug., 1901	123	From 13,000 to 40,000	14,500,000			
		Open	26 June, 1900, to 12 Mar., 1901	89	182,000 to 318,000	106,000,000	390 cubic yards.	89·3	

No.	Name of town or district.	Remarks.
47	York	